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Research Note

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Errors in Six and Twelve Hour Predictions of Upper Level Winds

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METEOROLOGICAL DEVELOPMENT LABORATORY PROJECT 8641

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Abstract

Analysis of a large sample of wind forecasts for 6- and 12- hour periods reveals that subjective forecasts are linearly related to the wind at the beginning of the forecast interval. This relationship enables one to develop a regression equation between forecast error and persistence error by means of which it is possible to extend the results derived from this sample.

The variation of forecast and persistence errors with geography, level and season is discussed. It is found that the maximum advantage of subjective forecasts over persistence is 10% for 6-hour periods and 20% for 12-hour periods.

Acknowledgments

The contribution of Captain Clifford D. Kern, USAF, to the success of this research is gratefully acknowledged. Captain Kern made the original suggestion that the study be undertaken. He was instrumental in obtaining the data. His assistance in the preliminary stages of analysis was invaluable.

The author also wishes to express his appreciation to Sister M. Leonarda and her student assistants on the Math Project at Regis College who worked for more than a year at the task of performing the tedious computations of forecast error statistics which appear in this report.

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GENERAL TERMINOLOGY

Vector: a capital letter with an arrow above it. A list of all vector quantities appears on page 4.

Vector Magnitude: a capital letter.

Angle between two vectors: a Greek letter.

Vector Component: lower case pair of letters, the first of which is the same as the vector designation and the second is either x (west-east, positive from the west) or y (south-north, positive from the south).

SPECIFIC SYMBOLS

p	**forecast period**
i	a particular observation
N	total number of cases
σ^2	vector variance of the wind (climatic variance)
σ	standard vector deviation of the wind
∇	vector mean wind (magnitude)
VFE	vector variance of forecast errors
MF	mean square error of subjective forecasts
RF	root mean square error of subjective forecasts
MP	mean square error of persistence forecasts
RP	root mean square error of persistence forecasts
r	vector persistence correlation
a, b, β	constants in linear regression equations
ρ	coefficient of correlation between an observed and an estimated quantity
RVP	percent reduction in variance of persistence forecasts with respect to climatology
FA	forecast advantage over persistence

Errors in Six- and Twelve-Hour Predictions of Upper-Level Winds

1. INTRODUCTION

1.1 Background

Verification data for 6- and 12-hour predictions of upper-level winds are singularly lacking in the meteorological literature. The few verification studies available are mainly concerned with 24-hour forecasts, since this is the interval which has proved to be most applicable to a wide variety of military and civilian operations (e. g. McRae and Phillpot, 1959, Aubert et al, 1960, Darling and Land, 1962). However, the advent of jet aircraft and missiles, operating in an electronically controlled environment where the time scale is ever shrinking, has given rise to the need for accurate short-period wind forecasts. The aim of this paper is to specify our present capability to provide such forecasts.

The most complete data available on wind forecast errors, based on data collected prior to 1958, is contained in an Air Weather Service report by Ellsaesser (1957) which outlines the findings of many investigators concerning errors in persistence and subjective forecasts for periods of 6 to 48 hours as a function of atmospheric level and season. However the usefulness of this report is limited by the fact that the 6-hour data were obtained entirely by extrapolation from 12 and 24 hours. Furthermore, the verification data from widely separated geographic regions were combined to produce a set of mean statistics. These crude procedures were necessitated by the lack of an adequate data sample at the time this report was written.

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* Semi-automatic Ground Environment.

(Author's manuscript received for publication, 18 May 1962)

In the past four years the 4th Weather Wing, Air Weather Service has conducted a series of wind forecast verification programs in an effort to appraise its current capability to support the SAGE* System of Air Defense. The forecast periods of interest were 6 and 12 hours; the levels: 30,000 and 40,000 ft. During the thirteen-month period, December 1958 through December 1959, 16 upper air stations in the U. S. participated in this verification program. The Air Weather Service has published two preliminary studies based on these data (4WWSS, 1959), summarizing the results which were of immediate concern to SAGE operators. Lack of manpower and the press of other problems precluded completion of the analysis of this unique data sample.

In a recent paper Darling and Kern (1961) demonstrate the crucial effect of wind forecast errors on certain manned intercept tactics programmed for the SAGE system. Estimates of the magnitude of this wind effect suggest that accurate 6-hour forecasts would be needed to support these tactics.

A study by Darling (1960) on weather requirements of the forthcoming automated FAA* Air Traffic Control System indicates the desirability of wind predictions for periods of 6 hours to be entered in the memory of the flight control computer. This conclusion was corroborated by an analysis performed by Borg-Warner Corporation (1961) under FAA contract.

In the course of reviewing these and other operational problems it became apparent to the author that a detailed survey of current wind forecasting capability for short periods was long overdue. Such a survey would serve a dual purpose: (1) it would provide a basis for evaluating our current capacity to support operations such as those cited above; (2) where deficiencies in capability are discovered the study would indicate the degree of improvement required and hence the type of research program needed. Accordingly, it was decided that such a survey would be prepared at GRD, based on the 13 months of data collected by the Air Weather Service.**

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* Federal Aviation Agency

** The author is indebted to Col. Robert Bundgaard, Scientific Services, 4th Weather Wing, for his cooperation in furnishing these data.

1.2 Data and Analysis

For each of the 16 stations (section 3) participating in the upper wind verification program the following data were tabulated by AWS units for the period December 1958 through December 1959:

Forecast period:	6 or 12 hours. Only Portland, Maine had data for both periods.
Levels:	30,000 and 40,000 feet.
Time:	Time of the beginning and ending of each forecast period, GMT.
Winds (direction [degrees] and speed [knots]):	Observed wind at the beginning of the forecast period. Subjective wind forecast made at the beginning and pertaining to the end of the period.
	Observed (verifying) wind at the end of the period.

Because the verifying procedure was carried out as a supplementary activity by weather units in the field, there were certain times when this duty had to be neglected in favor of more urgent operational responsibilities. As a result the station samples all contain gaps and in some cases entire months are missing (e. g. one of the stations was moved from Albuquerque to El Paso during the winter 1958-59). The total number of verifications possible during this period is 28,512 six-hour forecasts and 12,672 twelve-hour. The corresponding actual numbers were 19,749 (69%) and 8,586 (68%). The number of cases for each station, level, month and season are listed in the tables of Section 3.

The following quantities were computed from these data:

Vector variance of the wind - i. e., the climatic variance.

Root mean square error of persistence forecasts. This is the error which results when the measured wind at the beginning of a period is used as a forecast of the wind at the end of the period.

Root mean square error of subjective forecasts.

Equations for computing these quantities are developed in Section 2. The calculated monthly and seasonal errors are presented and discussed in Section 3.

Through the application of regression theory it is proved in Section 4 that a subjective short-period forecast is essentially a linear function of the observed wind at the beginning of the period. Making use of this property,

a linear equation relating forecast error to persistence error is developed and applied to a large sample of wind data to generate estimates of the forecast error over the entire U. S. for all seasons.

Finally, the relative merits of persistence and subjective forecasts are explored in detail. Charts showing the geographical distribution of quantities measuring the performance of these two types of forecasts are presented.

2. METHODOLOGY

The equations used to compute the vector variance, forecast error and persistence error are developed in this section. The following terminology has been adopted:

A capital letter with an arrow above it designates a vector. The absence of an arrow over a capital letter indicates the magnitude of the vector - e. g. V is the magnitude of $\vec{V}$. Greek letters denote the angle between two vectors. The following vectors appear in the equations. (The subscript, i, denotes a particular observation):

$\vec{V}_i$	the measured wind
$\bar{\vec{V}}$	the vector mean wind for a sample of N observations
$\vec{D}_i$	vector deviation from the mean
$\vec{F}_i$	forecast wind vector
$\bar{\vec{F}}$	vector mean forecast wind
$\vec{E}_i$	forecast error
$\vec{V}_{i-p}$	the measured wind at the (i-p) th observation, where p is the forecast period
$\vec{P}_i$	persistence error

Vector components are denoted by a lower case pair of letters, the first of which is the same as the vector designation and the second is either x (west-east) or y (south-north) - e. g., $\vec{F}_i$ has components fx_i and fy_i.

2.1 Vector Variance of the Wind, σ^2

The deviation of a wind from the mean is written as:

$$\vec{D}_i = \vec{V}_i - \overline{\vec{V}}$$

By the law of cosines:

$$D_i^2 = V_i^2 + \overline{V}^2 - 2V_i\overline{V} \cos \Theta_i$$

where Θ_i is the angle between $\vec{V}_i$ and $\overline{\vec{V}}$.

By definition (Brooks, 1953):

$$\sigma^2 = \frac{1}{N} \sum_{i=1}^{N} D_i^2 = \frac{1}{N} \sum_{i=1}^{N} [V_i^2 + \overline{V}^2 - 2V_i\overline{V} \cos \Theta_i] \tag{1}$$

Since $V_i \cos \Theta_i$ is the component of $\vec{V}_i$ in the direction of $\overline{\vec{V}}$ it follows that

$$\frac{1}{N} \sum_{i=1}^{N} V_i \cos \Theta_i = \overline{V} \tag{2}$$

Substituting (2) into (1) and reducing:

$$\sigma^2 = \frac{\sum_{i=1}^{N} V_i^2}{N} - \overline{V}^2 \tag{3}$$

Note that the first term is simply the mean sum of squares of N wind speeds. The second term must be computed from wind components:

$$\overline{V}^2 = \left(\frac{\sum_{i=1}^{N} vx_i}{N}\right)^2 + \left(\frac{\sum_{i=1}^{N} vy_i}{N}\right)^2 \qquad (4)$$

2.2 Forecast Errors

The expression for the variance of forecast errors is derived from the vector forecast error, $\vec{E}_i$.

$$\vec{E}_i = (\vec{F}_i - \overline{\vec{F}}) - (\vec{V}_i - \overline{\vec{V}}) \qquad (5)$$

The vector variance of forecast errors, VFE, is:

$$VFE = \frac{1}{N} \sum_{i=1}^{N} E_i^2$$

$$= \frac{1}{N} \sum_{i=1}^{N} (F_i - \overline{F})^2 + (V_i - \overline{V})^2 - 2 (F_i - \overline{F})(V_i - \overline{V}) \cos \alpha_i$$

where α_i is the angle between $\vec{V}_i - \overline{\vec{V}}$ and $\vec{F}_i - \overline{\vec{F}}$.

Substituting equation (3):

$$VFE = \frac{\sum_{i=1}^{N} F_i^2}{N} - \overline{F}^2 + \frac{\sum_{i=1}^{N} V_i^2}{N} - \overline{V}^2 - \frac{2}{N} \sum_{i=1}^{N} (F_i - \overline{F})(V_i - \overline{V}) \cos \alpha_i \qquad (5a)$$

The computation of VFE is quite lengthy because of the last term in this equation which involves the following calculations:

Let ϕ_i be the direction of the vector, $\vec{F}_i - \overline{\vec{F}}$; ψ_i the direction of $\vec{V}_i - \overline{\vec{V}}$. Then:

$$F_i - \overline{F} = [(fx_i - \overline{fx})^2 + (fy_i - \overline{fy})^2]^{\frac{1}{2}}$$

$$V_i - \overline{V} = [(vx_i - \overline{vx})^2 + (vy_i - \overline{vy})^2]^{\frac{1}{2}}$$

$$\phi_i = \tan^{-1}\left(\frac{fy_i - \overline{fy}}{fx_i - \overline{fx}}\right)$$

$$\psi_i = \tan^{-1}\left(\frac{vy_i - \overline{vy}}{vx_i - \overline{vx}}\right)$$

$$\alpha_i = \phi_i - \psi_i$$

All of the above quantities must be computed for each day and substituted into Equation (5) in order to determine VFE.

Equation (5) can be simplified in the case where the forecasts are unbiased (i.e. $\overline{\vec{V}} = \overline{\vec{F}}$).

$$\vec{E}_i = \vec{V}_i - \vec{F}_i \tag{6}$$

The mean square error of the forecasts, MF, is defined by the following equation:

$$MF = \frac{1}{N} \sum_{i=1}^{N} E_i^2 = \frac{1}{N} \sum_{i=1}^{N} [V_i^2 + F_i^2 - 2V_iF_i \cos \beta_i] \tag{6a}$$

where β_i is the angle between $\vec{V}_i$ and $\vec{F}_i$.

Since Equation (6a) involves only vector magnitudes and angles, it is possible to compute MF directly from tabulated values of $\vec{V}_i$ and $\vec{F}_i$, thereby avoiding the recourse to components required in evaluating Equation (5a).

Although there is no reason to assume that wind forecasts are biased it was decided to test this hypothesis on actual data. Four months of 12-hour forecast data for Portland, Maine were selected for this purpose. Quantities computed were $\overline{\vec{V}}$, $\overline{\vec{F}}$, VFE and MF. The results, presented in Table 1, clearly substantiate the hypothesis that $\overline{\vec{V}} = \overline{\vec{F}}$ as the small difference between these two mean vectors is below the noise level of the data. As a consequence VFE is very nearly equal to MF and we are justified in using Equation (6a) rather than the more complex Equation (5a) in computing forecast errors.

2.3 Persistence Errors

When the wind at the beginning of a forecast period is used as a forecast of the wind at the end of the period, p, then the error due to persistence may be written:

$$\vec{P}_i = \vec{V}_i - \vec{V}_{i-p} \tag{7}$$

The mean square error of persistence forecasts, MP, is then defined as:

$$MP = \frac{1}{N} \sum_{i=1}^{N} P_i^2 = \frac{1}{N} \sum_{i=1}^{N} \left[V_i^2 + V_{i-p}^2 - 2 V_i V_{i-p} \cos \gamma_i \right] \tag{7a}$$

where γ_i is the angle between $\vec{V}_i$ and $\vec{V}_{i-p}$.

2.4 Persistence Correlation

Durst (1954) has derived the following expression for the stretch correlation, r, between vectors $\vec{V}$ and $\vec{W}$:

$$r = \frac{\frac{1}{N} \sum_{i=1}^{N} \vec{D}_{v_i} \cdot \vec{D}_{w_i}}{\sigma_v \sigma_w} \tag{8}$$

Table 1. Wind Data, Portland, Maine; Winter

$\vec{\bar{V}}$ vector mean wind.

$\vec{\bar{F}}$ vector mean forecast wind.

VFE variance of forecast errors.

MF mean square error of forecasts.

			$\vec{\bar{V}}$		$\vec{\bar{F}}$			
Month	Year	Level K ft	Direction (deg.)	Speed (kts)	Direction (deg.)	Speed (kts)	VFE (kts^2)	MF (kts^2)
Dec	1958	30	261	79.6	261	81.8	1275	1312
		40	260	76.3	259	76.1	686	682
Jan	1959	30	267	76.9	269	79.8	1030	1034
		40	270	73.6	269	76.2	928	929
Feb	1959	30	273	82.5	272	85.0	1396	1405
		40	278	88.6	276	86.7	806	822
Dec	1959	30	265	66.3	269	66.5	1550	1454
		40	260	57.9	266	61.6	700	758
Win	Dec'58	30	268	79.6	268	82.2		1262
	-Feb'59	40	270	79.1	268	79.3		812

where $\vec{D}_{v_i}$ and $\vec{D}_{w_i}$ are deviations from the respective means; σ_v and σ_w are standard vector deviations. The dot in the numerator denotes a scalar product. In the case where the two winds are measured at the beginning and end of a period, p, at a particular station, then

$$\vec{V} = \vec{V}_{i-p}; \quad \vec{W} = \vec{V}_i$$

$$\overline{\vec{V}}_{i-p} = \overline{\vec{V}}_i$$

and $\sigma_v = \sigma_w = \sigma$, the standard vector deviation of the wind. Equation (8) then reduces to the vector persistence correlation:

$$r = \frac{\frac{1}{N}\sum_{i=1}^{N} \vec{D}_{i-p} \cdot \vec{D}_i}{\sigma^2} = \frac{\frac{1}{N}\sum_{i=1}^{N} D_{i-p} D_i \cos \phi_i}{\sigma^2} \tag{9}$$

where ϕ_i is the angle between $\vec{D}_{i-p}$ and $\vec{D}_i$. Expressing Equation (7) in terms of deviations from the mean, substituting into Equation (7a), reducing by the law of cosines and introducing (9):

$$MP = 2\sigma^2 (1-r) \tag{10}$$

or

$$RP = \sigma\left(2(1-r)\right)^{\frac{1}{2}} \tag{11}$$

3. MONTHLY AND SEASONAL FORECAST ERRORS

Equations (3), (6a), (7a) and (9) of Section 2 have been used to compute monthly and seasonal values of the vector variance, forecast and persistence mean square errors, and persistence correlation at 30,000 and 40,000 ft for the thirteen-month period, December 1958 through December 1959. The forecast period was either 6 or 12 hours for the following stations (synoptic index numbers appear in parentheses):

6-hour forecasts	12-hour forecasts
Santa Monica	El Paso (270)
International Falls (747)	Montgomery (226)
Sault Saint Marie (734)	Spokane (785)
Great Falls (775)	Flint, Mich. (637)
Topeka (456)	Oakland (493)
Norfolk (308)	Seattle (793)
LaGuardia (503)	Oklahoma City (353)
Portland, Maine (606)	Portland, Maine (606)
Pepperrell AFB, Nfld (807)	

Quantities tabulated are:

- σ standard vector deviation of the wind, knots
- $RP = [MP]^{\frac{1}{2}}$, root mean square error of the persistence forecasts, knots
- $RF = [MF]^{\frac{1}{2}}$, root mean square error of the subjective forecasts, knots
- r the persistence correlation
- N number of cases

Tables 2 and 3 contain the monthly data for 6 and 12 hours, respectively. A blank in the tables indicates that data are either missing or insufficient.

3.1 Monthly Forecasts

These data are discussed in the following paragraphs in terms of the variation of error with forecast period, forecast type, height, geography and time.

3.1.1. SIX-HOUR VS TWELVE-HOUR FORECASTS

The effect of forecast period can best be seen by comparing the data for Portland, Maine in Tables 2h (p. 21) and 3h (p. 30). The 12-hour values of RP and RF generally range from six to ten knots higher than the corresponding 6 hour values. The difference between 6-and 12-hour errors is greatest in winter, least in summer. Annual average values of RF are about 24 kts for 6 hours and 31 kts for 12 hours.

3.1.2. PERSISTENCE VS SUBJECTIVE FORECASTS

The salient feature of the comparison between RP and RF is the tendency of persistence and forecast errors to vary in parallel in the sense that large values of RP are associated with large values of RF and vice versa. Furthermore, it may be seen that persistence errors of about 20 kts and above are preponderantly associated with values of RF which are less than RP. Conversely, for persistence errors of less than 20 kts RF tends to be greater than

the corresponding RP.

3.1.3. VARIATION OF ERRORS WITH HEIGHT

During the winter months forecast errors (both RP and RF) are larger at 30,000 ft than at 40,000 ft. In the summer the reverse is true for most stations. The standard vector deviation of the wind exhibits the same behavior.

3.1.4. GEOGRAPHICAL DISTRIBUTION

Both the six-and twelve-hour errors show the same type of distribution with geography. Centers of maximum error are located in the northeastern and northwestern corners of the country. Smallest errors occur over the north-central and southern portions. Errors over the central U. S. are intermediate in magnitude.

3.1.5. ANNUAL VARIATION

At 30,000 ft the general pattern of annual variation in forecast error consists of a marked minimum in the summer months and considerably higher values during the remainder of the year. The maximum error may occur in any season except summer, but winter seems to be the favored time. At 40,000 ft minimum errors tend to be registered in winter or spring; maximum errors in summer or fall.

3.2 Seasonal Forecasts

In order to increase the sample size for each error statistic with the aim of achieving a more stable result the data for individual months were combined into seasons in the following manner:

Months	Season
Dec '58, Jan, Feb '59	Winter
Mar, Apr, May '59	Spring
June, Jul, Aug '59	Summer
Sep, Oct, Nov '59	Fall

Values of σ, MP, MF and r were computed for each season using the same equations as before. Six-hour errors are shown in Table 4, 12-hour values in Table 5. The remarks in paragraphs 3.1.1. through 3.1.5. above apply to these seasonal errors.

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Table 2. Monthly Wind Statistics and Six-Hour Forecast Errors

σ standard vector deviation of the wind.
RP root mean square error of persistence forecasts.
RF root mean square error of subjective forecasts.
r six hour persistence correlation.
N number of cases.

a. SANTA MONICA

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30	27.3	16.6	16.9	.82	101
	40	31.1	16.7	17.0	.86	102
January 1959	30	33.6	23.2	20.7	.76	118
	40	34.8	17.1	24.6	.88	112
February	30	44.1	25.2	20.1	.84	87
	40	29.5	17.4	14.3	.83	76
March	30	26.3	20.3	18.6	.70	116
	40	34.4	19.4	18.7	.84	114
April	30	33.8	17.7	17.0	.86	116
	40	35.5	17.0	18.4	.88	114
May	30	33.1	20.9	19.3	.80	114
	40	27.5	15.7	16.6	.84	110
June	30	21.9	13.2	14.0	.82	111
	40	27.1	15.4	15.5	.84	105
July	30	19.0	8.3	13.1	.91	109
	40	24.8	10.1	10.1	.92	114
August	30	21.4	12.4	12.3	.84	117
	40	29.2	12.2	13.1	.91	119
September	30	22.2	14.2	13.2	.80	111
	40	26.1	14.7	14.3	.84	108
October	30	31.8	18.5	17.3	.83	118
	40	35.5	19.1	17.1	.86	115
November	30	28.9	19.1	19.4	.78	117
	40	35.6	19.3	19.3	.85	115
December	30	47.8	25.4	21.9	.86	112
	40	56.0	22.6	16.1	.92	99

Table 2. Monthly Wind Statistics and Six-Hour Forecast Errors (continued)

b. <u>INTERNATIONAL FALLS (747)</u>

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30					
	40					
January 1959	30	43.5	24.9	26.8	.82	111
	40	33.8	15.4	20.6	.90	102
February	30	40.7	24.8	23.6	.81	100
	40	25.9	15.6	16.3	.82	98
March	30	40.5	30.0	27.2	.73	98
	40	19.7	12.8	13.3	.79	97
April	30	49.8	27.4	25.7	.85	96
	40	27.0	16.5	15.9	.81	93
May	30	51.7	16.0	28.2	.95	101
	40	44.4	21.3	23.2	.88	96
June	30	39.1	24.1	20.8	.81	95
	40	42.0	22.8	21.0	.85	91
July	30	31.3	22.1	15.9	.75	104
	40	34.2	22.7	18.0	.78	104
August	30	36.9	21.6	27.1	.83	92
	40	37.0	22.0	20.0	.82	94
September	30	46.4	28.2	22.9	.82	105
	40	42.2	26.8	23.1	.80	95
October	30	45.3	29.8	21.7	.78	94
	40	39.0	17.4	12.9	.90	91
November	30	55.9	32.0	26.8	.84	101
	40	41.3	22.7	19.4	.85	88
December	30	52.5	25.5	28.7	.88	102
	40	36.9	21.7	21.7	.83	95

Table 2. Monthly Wind Statistics and Six-Hour Forecast Errors (continued)

c. SAULT STE MARIE (734)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30	39.5	28.8	25.1	.73	106
	40	23.7	16.6	16.0	.76	103
January 1959	30	50.8	27.4	20.6	.85	103
	40	37.6	17.4	16.1	.89	95
February	30	44.4	30.5	29.3	.76	83
	40	28.0	17.9	19.3	.80	73
March	30	45.2	29.0	23.3	.79	109
	40	23.4	17.4	15.5	.72	101
April	30	45.2	25.2	21.1	.84	98
	40	29.6	19.3	14.9	.79	92
May	30	39.0	26.9	24.7	.76	105
	40	36.6	25.1	19.9	.76	101
June	30	40.9	24.4	20.2	.82	106
	40	43.7	22.3	18.0	.87	101
July	30	33.6	18.3	15.0	.85	91
	40	35.1	20.8	17.8	.82	86
August	30	28.1	18.4	19.1	.79	106
	40	32.0	22.9	19.2	.74	98
September	30	46.5	30.8	23.9	.78	95
	40	42.0	25.1	26.3	.82	90
October	30	43.0	28.0	22.0	.79	106
	40	38.2	20.5	8.6	.86	101
November	30	52.2	29.1	13.5	.84	90
	40	39.3	18.0	18.0	.89	77
December	30	51.7	27.2	24.8	.86	106
	40	30.3	16.4	15.8	.85	95

Table 2. Monthly Wind Statistics and Six-Hour Forecast Errors (continued)

d. GREAT FALLS (775)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30	45.5	31.6	31.5	.76	90
	40	35.3	23.2	24.7	.78	85
January 1959	30	46.1	28.2	25.8	.81	112
	40	33.7	20.3	22.9	.82	98
February	30	44.4	25.9	25.8	.83	84
	40	26.8	10.7	13.2	.92	80
March	30	46.8	29.9	32.1	.80	118
	40	29.4	16.2	19.5	.85	113
April	30	51.0	25.5	27.3	.88	94
	40	36.0	18.5	20.7	.87	92
May	30	46.4	16.8	23.6	.93	101
	40	33.5	19.9	19.1	.82	97
June	30	33.8	22.7	23.9	.77	102
	40	35.5	20.9	23.9	.83	102
July	30	30.4	19.3	19.5	.80	118
	40	44.1	36.2	36.3	.66	118
August	30	34.0	26.1	25.4	.70	114
	40	35.5	19.6	21.3	.85	105
September	30	40.3	25.1	25.4	.81	
	40	32.4	18.9	22.8	.83	
October	30					
	40					
November	30					
	40					
December	30					
	40					

Table 2. Monthly Wind Statistics and Six-Hour Forecast Errors (continued)

e. TOPEKA (456)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30	45.4	29.2	27.2	.79	76
	40	33.0	19.0	18.4	.84	69
January 1959	30	50.0	30.3	29.0	.82	96
	40	45.2	22.5	22.3	.88	79
February	30	34.9	28.0	20.3	.68	87
	40	37.5	26.4	20.1	.75	70
March	30	41.5	30.0	28.5	.74	104
	40	25.0	22.2	17.4	.61	99
April	30	45.9	26.1	22.2	.84	97
	40	40.0	20.7	21.1	.86	92
May	30	31.7	24.9	22.9	.69	96
	40	35.7	26.7	23.6	.72	92
June	30	23.7	15.2	9.4	.79	95
	40	32.6	20.6	21.9	.80	88
July	30	26.7	21.1	21.5	.69	100
	40	29.2	24.7	24.5	.64	99
August	30	26.3	18.0	17.5	.77	68
	40	35.6	22.2	22.0	.81	65
September	30	33.5	18.4	15.7	.85	92
	40	37.4	28.7	24.4	.71	89
October	30	43.1	30.4	28.2	.75	97
	40	40.5	28.4	27.0	.75	91
November	30.	47.2	30.5	27.6	.79	111
	40	40.3	25.5	26.0	.80	102
December	30	43.4	31.3	27.2	.74	107
	40	44.0	25.7	26.2	.83	89

Table 2. Monthly Wind Statistics and Six-Hour Forecast Errors (continued)

f. NORFOLK (308)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30	44.4	32.5	33.9	.73	35
	40	44.5	27.8	26.3	.80	31
January 1959	30	44.8	30.3	24.7	.77	83
	40	37.2	20.6	28.0	.85	61
February	30	40.4	28.9	27.6	.74	78
	40	40.8	29.1	29.4	.74	62
March	30	49.0	37.0	25.6	.72	86
	40	35.4	22.6	23.6	.80	70
April	30	36.6	27.4	22.2	.72	101
	40	39.1	22.5	21.4	.83	97
May	30	38.0	18.1	19.2	.89	108
	40	36.5	18.3	17.7	.88	98
June	30	33.4	17.8	15.8	.86	110
	40	36.9	19.8	18.6	.86	100
July	30	18.9	12.5	12.0	.78	101
	40	28.4	16.9	16.4	.82	100
August	30	25.7	13.2	4.4	.87	99
	40	37.3	17.6	15.6	.89	87
September	30	28.8	12.3	13.4	.91	96
	40	39.7	17.8	17.7	.90	93
October	30	38.6	19.8	17.0	.87	107
	40	45.6	24.7	22.4	.85	101
November	30	40.1	29.3	24.4	.73	94
	40	43.2	23.0	24.0	.86	87
December	30	51.6	32.2	27.2	.80	102
	40	45.5	29.7	26.1	.79	68

Table 2. Monthly Wind Statistics and Six-Hour Forecast Errors (continued)

g. LAGUARDIA (503)

Month	Level (k ft)	σ knots	RP knots	RF knots	r	N
December 1958	30	47.7	36.5	34.4	.71	79
	40	35.1	23.1	22.7	.78	62
January 1959	30	50.5	26.8	27.0	.86	92
	40	37.5	24.1	23.0	.79	77
February	30	45.9	34.0	31.1	.73	82
	40	36.1	27.4	28.2	.71	69
March	30	47.5	32.8	28.7	.76	95
	40	33.6	21.0	18.8	.80	86
April	30	47.3	37.8	33.7	.68	89
	40	38.9	25.3	22.2	.79	88
May	30	44.4	19.9	21.4	.90	116
	40	46.2	23.0	21.5	.88	101
June	30	31.1	23.5	23.4	.72	110
	40	37.3	21.7	20.2	.83	108
July	30	27.7	17.9	15.2	.79	105
	40	36.6	21.2	18.3	.83	105
August	30	25.3	17.2	17.0	.77	108
	40	38.5	20.3	19.9	.86	108
September	30	35.6	18.8	19.5	.86	106
	40	43.7	24.2	20.7	.85	104
October	30	40.4	22.3	20.3	.85	102
	40	42.8	24.5	26.5	.84	98
November	30	48.2	29.2	25.6	.82	89
	40	44.0	24.7	24.9	.84	80
December	30					
	40					

Table 2. Monthly Wind Statistics and Six-Hour Forecast Errors (continued)

h. PORTLAND (606)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30					
	40					
January 1959	30	47.3	28.2	28.8	.82	91
	40	37.2	19.6	21.0	.86	87
February	30	46.8	33.7	27.3	.74	90
	40	34.3	26.0	22.5	.71	73
March	30	46.6	31.6	26.6	.77	93
	40	28.9	17.3	16.4	.82	88
April	30	43.6	30.0	23.9	.76	99
	40	34.0	20.8	21.0	.81	93
May	30	39.7	22.4	19.1	.84	106
	40	39.6	20.9	19.4	.86	102
June	30	42.9	22.7	23.8	.86	101
	40	47.0	18.5	17.5	.92	95
July	30	34.4	27.3	18.9	.68	95
	40	41.0	25.1	20.9	.81	91
August	30	33.8	20.4	22.8	.82	81
	40	43.0	22.9	26.4	.86	76
September	30	38.6	20.3	21.0	.86	87
	40	42.8	21.5	23.6	.87	83
October	30	37.5	26.2	22.4	.76	89
	40	35.3	25.7	22.7	.74	86
November	30	46.6	34.3	29.0	.73	90
	40	41.7	25.[illegible]	21.9	.82	74
December	30	47.9	34.5	24.6		71
	40	28.6	18.7	15.4		60

Table 2. Monthly Wind Statistics and Six-Hour Forecast Errors (continued)

i. PEPPERRELL (807)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30					
	40					
January 1959	30	48.2	30.0	24.7	.81	100
	40	37.6	19.6	16.8	.86	99
February	30	46.6	28.1	28.8	.82	83
	40	33.0	18.4	17.7	.85	83
March	30	46.2	32.4	32.2	.75	90
	40	26.5	18.3	24.0	.76	85
April	30	56.6	33.0	33.0	.83	108
	40	35.3	21.0	20.3	.82	108
May	30	62.6	32.2	36.4	.87	118
	40	49.5	20.7	22.8	.13	112
June	30	55.8	27.9	26.1	.88	112
	40	50.9	24.8	24.2	.88	106
July	30	38.2	24.0	24.3	.80	117
	40	41.4	24.5	26.0	.82	116
August	30	37.3	22.0	23.1	.83	114
	40	45.4	22.4	21.8	.88	116
September	30	43.1	29.3	31.6	.77	120
	40	44.7	26.4	28.0	.83	120
October	30	49.8	30.8	31.2	.81	124
	40	46.8	30.0	28.5	.80	119
November	30	52.7	33.1	32.7	.80	112
	40	45.1	29.6	28.2	.78	95
December	30	49.0	35.6	33.8	.74	109
	40	31.0	18.3	18.6	.83	102

Table 3. Monthly Wind Statistics and Twelve-Hour Forecast Errors

σ standard vector deviation of the wind.

RP root mean square error of persistence forecasts.

RF root mean square error of subjective forecasts.

r twelve-hour persistence correlation.

N number of cases.

a. EL PASO (270)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30					
	40					
January 1959	30					
	40					
February	30					
	40					
March	30	25.6	34.6	37.4	.09	15
	40	28.0	30.9	32.6	.39	14
April	30	20.5	16.0	18.4	.69	31
	40	30.3	24.3	21.3	.68	20
May	30	20.0	16.2	18.7	.67	37
	40	25.7	20.9	20.8	.67	29
June	30	24.7	16.9	17.0	.77	54
	40	30.3	23.0	23.9	.71	48
July	30	16.8	14.3	14.8	.64	54
	40	21.1	18.8	18.9	.60	54
August	30	12.8	10.7	10.7	.65	52
	40	17.5	16.4	16.7	.56	54
September	30	20.8	16.3	14.8	.70	49
	40	24.1	16.0	16.6	.78	43
October	30	29.4	24.1	21.2	.66	44
	40	28.3	26.1	23.7	.58	38
November	30	28.4	28.7	24.6	.49	34
	40	26.3	27.4	25.7	.46	18
December	30	31.5	34.3	31.5	.41	23
	40	23.4	27.8	33.9	.29	13

Table 3. Monthly Wind Statistics and Twelve-Hour Forecast Errors (continued)

b. MONTGOMERY (226)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30					
	40					
January 1959	30	36.2	32.7	30.5	.59	51
	40	35.2	32.6	30.7	.57	51
February	30	35.8	34.7	36.7	.53	54
	40	34.5	29.1	33.8	.64	46
March	30	37.0	33.3	28.6	.60	50
	40	38.7	32.0	28.8	.66	41
April	30	35.2	26.0	24.8	.73	36
	40	42.7	33.5	31.3	.69	33
May	30	25.5	15.8	14.4	.81	56
	40	34.5	31.3	24.1	.59	56
June	30	25.9	19.2	22.0	.72	59
	40	35.6	24.9	21.9	.75	58
July	30	17.0	13.9	13.6	.67	59
	40	22.0	17.2	17.4	.70	59
August	30	19.1	16.2	15.5	.64	60
	40	25.2	19.3	22.9	.71	60
September	30	21.1	17.7	17.8	.65	55
	40	25.6	21.8	21.5	.64	54
October	30	33.3	23.8	22.1	.74	56
	40	41.4	26.5	24.2	.80	50
November	30					
	40					
December	30	37.7	38.2	31.5	.49	52
	40	38.3	39.1	32.3	.48	51

Table 3. Monthly Wind Statistics and Twelve-Hour Forecast Errors (continued)

d. FLINT (637)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30	41.5	47.6	42.6	.34	42
	40	22.4	16.6	23.0	.73	37
January 1959	30	51.0	42.1	32.3	.66	49
	40	37.0	28.4	23.9	.71	46
February	30	39.3	38.1	33.3	.53	41
	40	29.1	27.6	24.0	.55	33
March	30	38.1	40.1	30.3	.45	52
	40	22.5	22.2	18.5	.51	50
April	30	40.6	43.3	32.6	.43	49
	40	29.1	25.0	17.5	.63	47
May	30	32.3	25.7	22.2	.68	54
	40	33.5	30.4	24.7	.59	52
June	30	37.5	24.6	19.1	.78	47
	40	45.0	30.2	24.5	.78	47
July	30	28.4	25.9	17.1	.58	57
	40	33.4	27.4	25.7	.66	53
August	30	25.5	21.7	19.7	.64	45
	40	31.2	24.0	22.5	.70	45
September	30					
	40					
October	30					
	40					
November	30					
	40					
December	30					
	40					

Table 3. Monthly Wind Statistics and Twelve-Hour Forecast Errors (continued)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30					
	40					
January 1959	30	52.4	40.1	37.1	.71	62
	40	37.2	25.5	25.8	.77	58
February	30	45.1	35.0	29.0	.70	54
	40	31.8	21.0	24.3	.78	54
March	30	48.8	46.8	37.1	.54	62
	40	26.2	23.1	22.5	.61	62
April	30	49.1	31.9	32.4	.79	56
	40	42.0	24.5	19.1	.83	54
May	30	47.8	29.0	32.3	.82	58
	40	36.6	21.7	17.3	.82	58
June	30	38.6	28.3	16.8	.73	56
	40	37.5	27.2	24.9	.74	52
July	30	28.5	27.3	17.9	.54	60
	40	23.0	23.5	20.9	.48	60
August	30	37.0	28.4	24.7	.70	62
	40	38.9	30.5	25.9	.69	62
September	30	53.5	37.9	34.8	.75	58
	40	46.4	28.4	22.9	.81	57
October	30	54.8	39.0	32.2	.75	62
	40	45.8	32.2	26.1	.75	57
November	30	46.5	43.7	21.4	.56	60
	40	41.3	35.9	29.8	.62	51
December	30	50.7	45.5	35.5	.60	62
	40	37.4	28.4	28.1	.71	60

Table 3. Monthly Wind Statistics and Twelve-Hour Forecast Errors (continued)

e. OAKLAND (493)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30	31.9	26.3	24.5	.66	50
	40	32.3	21.7	23.1	.77	50
January 1959	30	45.1	33.4	30.9	.73	57
	40	43.6	33.4	32.3	.71	54
February	30	50.5	33.8	29.9	.78	43
	40	32.7	24.9	22.6	.71	38
March	30	29.1	28.0	24.8	.54	60
	40	30.6	31.3	28.1	.48	56
April	30	34.7	28.0	25.9	.68	58
	40	34.0	23.6	26.2	.76	59
May	30	42.0	36.3	33.2	.63	62
	40	35.8	28.2	29.0	.69	62
June	30	31.8	22.3	20.5	.75	57
	40	38.0	28.6	23.3	.72	58
July	30	18.4	16.0	14.5	.62	56
	40	21.9	18.5	18.7	.64	56
August	30	28.2	21.6	22.2	.71	58
	40	31.9	23.5	23.5	.73	58
September	30	37.1	26.3	24.7	.75	58
	40	39.1	27.8	20.6	.75	57
October	30	32.6	24.0	24.3	.73	53
	40	34.4	30.7	26.5	.60	55
November	30	28.8	28.6	28.2	.51	49
	40	31.6	30.6	31.5	.53	48
December	30	46.2	35.7	33.0	.70	48
	40	47.7	40.3	30.4	.64	36

Table 3. Monthly Wind Statistics and Twelve-Hour Forecast Errors (continued)

f. SEATTLE (793)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30	41.2	37.3	38.7	.59	34
	40	31.8	29.5	32.1	.57	33
January 1959	30	65.0	47.0	42.8	.74	58
	40	44.6	28.7	25.8	.79	58
February	30	48.2	37.0	36.8	.70	54
	40	34.2	21.6	21.7	.80	54
March	30	47.7	49.7	40.9	.46	58
	40	30.0	28.6	24.1	.54	58
April	30	51.3	43.1	38.9	.65	60
	40	38.2	24.2	24.6	.80	60
May	30	54.5	35.2	34.9	.79	62
	40	37.7	22.8	21.3	.82	62
June	30	40.0	30.9	28.7	.70	60
	40	35.1	25.7	23.5	.73	60
July	30	30.6	27.2	24.2	.60	59
	40	27.3	22.8	21.2	.65	59
August	30	34.2	27.5	25.0	.68	59
	40	36.0	29.7	27.4	.66	57
September	30	59.1	36.2	33.7	.81	56
	40	56.3	27.6	25.2	.88	54
October	30	50.2	40.9	35.3	.67	62
	40	42.3	34.6	39.6	.66	57
November	30	44.4	43.5	39.2	.52	56
	40	38.9	36.2	31.9	.57	53
December	30	53.6	48.7	42.1	.59	58
	40	45.0	35.4	30.4	.69	53

Table 3. Monthly Wind Statistics and Twelve-Hour Forecast Errors (continued)

g. OKLAHOMA CITY (353)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30					
	40					
January 1959	30					
	40					
February	30					
	40					
March	30	42.5	35.9	35.4	.64	41
	40	31.8	27.7	27.2	.62	35
April	30	39.5	36.5	30.2	.57	56
	40	37.8	29.2	21.4	.70	56
May	30	23.9	24.1	20.4	.49	48
	40	32.6	33.3	28.6	.48	48
June	30	28.3	29.1	24.4	.47	52
	40	39.2	34.6	33.2	.61	48
July	30	26.0	21.6	20.5	.66	57
	40	28.4	21.9	23.0	.70	58
August	30	20.6	14.5	13.9	.75	58
	40	22.9	16.6	14.8	.74	58
September	30	28.1	20.6	20.1	.73	58
	40	31.1	25.8	24.8	.66	55
October	30	32.4	29.2	25.7	.59	57
	40	35.9	31.1	29.5	.63	57
November	30	45.5	42.3	35.1	.57	56
	40	40.1	37.7	36.0	.56	55
December	30	44.9	40.2	30.8	.60	60
	40	42.5	36.6	29.3	.63	60

Table 3. Monthly Wind Statistics and Twelve-Hour Forecast Errors (continued)

h. PORTLAND (606)

Month	Level (K ft)	σ knots	RP knots	RF knots	r	N
December 1958	30	48.7	52.0	36.2	.43	29
	40	32.5	28.6	26.1	.60	29
January 1959	30	48.0	39.8	32.2	.66	30
	40	38.2	34.0	30.5	.60	30
February	30	45.8	45.4	37.5	.51	38
	40	39.0	33.4	28.7	.63	33
March	30	43.4	45.0	37.1	.46	51
	40	28.4	26.3	22.5	.57	50
April	30	49.2	44.5	32.7	.59	56
	40	34.1	28.6	25.8	.65	48
May	30	39.9	28.8	29.5	.74	56
	40	40.2	31.9	27.8	.68	58
June	30	41.7	29.4	25.0	.75	55
	40	48.5	29.6	27.6	.81	54
July	30	35.0	28.5	23.8	.67	49
	40	44.1	32.3	28.6	.73	51
August	30	34.4	24.7	25.1	.74	55
	40	44.1	28.0	26.2	.80	54
September	30	38.2	33.8	33.3	.61	54
	40	39.8	29.1	29.8	.73	53
October	30	39.3	34.0	22.7	.62	50
	40	37.9	32.9	32.8	.62	46
November	30	48.8	49.4	36.4	.49	51
	40	45.7	34.7	33.2	.71	45
December	30	50.1	46.1	38.1		47
	40	34.6	31.4	27.5		31

Table 4. Seasonal Wind Statistics and Six-Hour Forecast Errors

σ standard vector deviation of the wind.

RP root mean square error of persistence forecasts.

RF root mean square error of subjective forecasts.

r six hour persistence correlation.

N number of cases.

a. SANTA MONICA

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	36.5	21.9	19.3	.82	306
	40	33.7	17.1	19.8	.87	290
Spring	30	32.1	19.7	18.3	.81	346
	40	34.4	17.4	18.0	.87	338
Summer	30	21.9	11.5	13.2	.86	337
	40	28.3	12.7	13.0	.90	338
Fall	30	29.4	17.5	16.9	.89	346
	40	34.1	17.9	17.1	.86	338

b. INTERNATIONAL FALLS (747)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	42.5	25.6	25.4	.82	211
	40	30.4	15.5	18.6	.87	200
Spring	30	49.1	25.1	27.0	.87	295
	40	34.4	17.2	18.0	.88	286
Summer	30	37.4	22.6	21.5	.82	291
	40	39.5	23.2	19.6	.83	289
Fall	30	50.5	30.0	23.9	.82	300
	40	41.5	22.7	19.0	.85	274

c. SAULT STE MARIE (734)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	45.6	28.8	24.9	.80	292
	40	31.1	17.2	17.0	.85	271
Spring	30	43.6	27.2	23.1	.81	312
	40	31.0	20.6	17.1	.78	294
Summer	30	35.9	20.6	18.4	.83	303
	40	38.6	22.1	18.4	.84	285
Fall	30	47.4	29.3	20.4	.81	291
	40	40.2	21.7	18.8	.86	268

Table 4. Seasonal Wind Statistics and Six-Hour Forecast Errors (continued)

d. GREAT FALLS (775)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	46.7	28.7	27.7	.81	286
	40	34.0	19.0	21.1	.84	263
Spring	30	50.1	25.0	28.1	.88	313
	40	34.8	18.2	19.8	.86	302
Summer	30	33.5	22.8	23.0	.77	334
	40	35.2	19.3	21.1	.85	325
Fall	30					
	40					

e. TOPEKA (456)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	45.4	29.2	25.8	.79	259
	40	40.8	22.8	20.4	.84	218
Spring	30	41.1	27.2	24.8	.78	297
	40	35.3	23.3	20.8	.78	283
Summer	30	26.1	18.3	16.9	.75	263
	40	32.9	22.7	23.0	.76	252
Fall	30	45.0	27.3	24.8	.82	300
	40	43.5	27.5	25.8	.80	282

f. NORFOLK (308)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	43.7	30.2	27.7	.76	196
	40	41.9	25.8	28.3	.81	154
Spring	30	46.4	27.9	22.2	.82	295
	40	42.8	21.1	20.7	.88	265
Summer	30	27.7	14.8	11.9	.86	310
	40	34.7	18.2	17.0	.86	287
Fall	30	40.6	21.5	18.7	.86	297
	40	48.4	22.1	21.5	.90	281

Table 4. Seasonal Wind Statistics and Six-Hour Forecast Errors (continued)

g. LAGUARDIA (503)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	49.6	32.4	30.8	.79	253
	40	37.7	25.0	24.8	.78	208
Spring	30	49.0	30.3	27.9	.81	300
	40	43.4	23.2	20.9	.86	275
Summer	30	28.8	19.8	18.9	.76	323
	40	38.3	21.1	19.5	.85	321
Fall	30	44.7	23.5	21.7	.86	297
	40	46.5	24.5	24.0	.86	282

h. PORTLAND (606)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	48.0	31.1	28.1	.79	181
	40	36.8	22.7	21.7	.81	160
Spring	30	45.9	28.1	23.2	.81	298
	40	37.6	19.8	19.1	.86	283
Summer	30	38.4	23.7	21.9	.81	277
	40	44.6	22.3	21.6	.88	262
Fall	30	47.5	27.6	24.4	.83	266
	40	46.7	24.2	22.7	.86	243

i. PEPPERRELL (807)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	47.7	29.2	26.6	.81	183
	40	35.8	19.0	17.2	.86	182
Spring	30	58.7	32.5	34.1	.85	316
	40	40.8	20.2	22.3	.88	305
Summer	30	44.9	24.7	24.5	.85	343
	40	46.2	23.9	24.1	.85	338
Fall	30	51.7	31.0	31.8	.82	356
	40	47.9	28.6	28.2	.82	334

Table 5. Seasonal Wind Statistics and Twelve-Hour Forecast Errors

σ standard vector deviation of the wind.

RP root mean square error of persistence forecasts.

RF root mean square error of subjective forecasts.

r twelve-hour persistence correlation.

N number of cases.

a. EL PASO (270)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30					
	40					
Spring	30	23.6	20.7	22.6	.61	83
	40	29.9	24.5	24.1	.66	63
Summer	30	21.3	14.2	14.5	.78	160
	40	27.0	19.4	19.9	.74	156
Fall	30	28.0	22.9	20.0	.66	127
	40	28.0	22.6	21.4	.68	99

b. MONTGOMERY (226)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	36.4	33.8	33.8	.57	105
	40	35.2	31.0	32.2	.61	97
Spring	30	41.5	25.7	22.9	.81	142
	40	49.8	32.1	27.6	.79	130
Summer	30	23.0	16.6	17.4	.74	178
	40	31.0	20.7	20.9	.78	177
Fall	30	31.4	21.0	20.1	.78	111
	40	38.2	24.2	22.8	.80	104

c. SPOKANE (785)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	52.5	37.8	33.6	.74	116
	40	37.5	23.4	25.1	.80	112
Spring	30	51.0	37.0	34.1	.74	176
	40	36.6	23.1	19.8	.80	174
Summer	30	35.7	28.0	20.2	.69	178
	40	34.6	27.3	24.0	.69	174
Fall	30	55.9	40.3	33.8	.74	180
	40	48.1	32.2	26.3	.78	165

Table 5. Seasonal Wind Statistics and Twelve-Hour Forecast Errors (continued)

d. FLINT (637)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	45.3	42.8	36.2	.56	132
	40	31.7	25.0	23.6	.69	116
Spring	30	37.6	36.9	28.6	.52	155
	40	29.0	26.2	20.6	.59	149
Summer	30	32.3	24.3	18.6	.72	149
	40	38.3	27.4	24.3	.74	145
Fall	30					
	40					

e. OAKLAND (493)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	43.6	31.3	28.6	.74	150
	40	38.3	27.5	26.8	.74	142
Spring	30	36.6	31.1	28.3	.64	180
	40	34.9	27.8	27.8	.68	177
Summer	30	27.7	20.2	19.4	.74	171
	40	32.8	23.9	22.0	.74	172
Fall	30	34.1	26.3	25.7	.70	160
	40	36.2	29.7	26.3	.66	160

f. SEATTLE (793)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	56.7	41.3	39.7	.73	146
	40	41.2	26.5	26.0	.79	145
Spring	30	54.2	42.9	38.2	.69	180
	40	37.1	25.3	23.4	.77	180
Summer	30	36.4	28.6	26.0	.69	178
	40	33.9	26.2	24.1	.70	176
Fall	30	52.8	40.3	36.1	.71	174
	40	48.0	33.0	32.9	.76	164

Table 5. Seasonal Wind Statistics and Twelve-Hour Forecast Errors (continued)

g. OKLAHOMA CITY (353)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30					
	40					
Spring	30	36.8	32.7	29.1	.60	145
	40	36.8	30.3	25.6	.66	139
Summer	30	24.8	22.3	19.9	.60	167
	40	31.0	24.8	24.2	.68	164
Fall	30	38.2	31.9	27.6	.65	171
	40	38.7	31.9	30.4	.66	167

h. PORTLAND (606)

Season	Level (K ft)	σ knots	RP knots	RF knots	r	N
Winter	30	48.0	45.9	35.5	.54	97
	40	38.8	32.2	28.5	.66	92
Spring	30	47.6	40.0	33.1	.65	163
	40	38.1	29.2	25.6	.71	156
Summer	30	38.3	27.6	24.7	.74	159
	40	46.7	29.9	27.5	.79	159
Fall	30	48.7	39.7	31.5	.67	155
	40	47.8	32.2	31.8	.77	144

4. GENERALIZATION OF RESULTS

4.1 Application of Regression Theory

The results in section 3 can be generalized by a straightforward application of regression theory. Let us assume that the forecast wind vector, $\vec{F}$, is a linear function of the observed wind at the beginning of the forecast period, $\vec{V}_{i-p}$.

Then:

$$\vec{F}_i - \overline{\vec{F}} = b\,(\vec{V}_{i-p} - \overline{\vec{V}}) = b\ \vec{D}_{i-p}$$

where b is a constant to be determined by least squares.

From Equation (5)

$$\vec{E}_i = b\,\vec{D}_{i-p} - \vec{D}_i \tag{12}$$

$$E_i^{\,2} = D_i^{\,2} + b^2 D_{i-p}^2 - 2b\,D_i\,D_{i-p}\cos\theta_i$$

where θ_i, is the angle between $\vec{D}_i$ and $\vec{D}_{i-p}$

$$MF = \frac{1}{N}\sum_{i=1}^{N} E_i^{\,2} = \frac{1}{N}\sum_{i=1}^{N}\left[D_i^{\,2} + b^2 D_{i-p}^2 - 2b\,D_i\,D_{i-p}\cos\theta_i\right]$$

$$= \sigma^2 + b^2\sigma^2 - 2br\,\sigma^2 \tag{12a}$$

by Equations (1) and (9).

Thus $MF = \sigma^2\,(1 - 2br + b^2)$

Differentiating with respect to b and setting the result equal to zero we find:

$$b = r$$

Hence

$$MF = \sigma^2\,(1 - r^2) \tag{13}$$

Substituting (10):

$$MF = \frac{1 - r^2}{2\,(1-r)}\ MP$$

$$= \left[\frac{1 + r}{2}\right]\ MP \tag{14}$$

or

$$RF = \left[\frac{1 + r}{2}\right]^{\frac{1}{2}} RP \tag{14a}$$

Equation (14a) explains the parallel fluctuation of RF and RP noted in paragraph 3. 1. 2. Although the coefficient, $\left[\frac{1 + r}{2}\right]^{\frac{1}{2}}$, is not a constant it is a slowly varying function of r. For example, the 6- and 12-hour persistence correlations in Tables 4 and 5 are seen to vary between about .6 and .9 for which $\left[\frac{1 + r}{2}\right]^{\frac{1}{2}}$ varies between .89 and .97. This suggests that a linear regression equation linking RF and RP should fit the error data quite well. In order to test this idea a linear equation of similar form to (14a) was fitted to the data in Tables 4 and 5 by least squares. The regression coefficient in this equation was then compared with the coefficient in Equation (14a) for a particular case. Standard errors were also computed for the two equations.

Let $y = RF$ and $x = RP$, $\sigma_y{}^2$ and $\sigma_x{}^2$ are variances, $\overline{x}$ and $\overline{y}$ are mean values, ρ is the coefficient of correlation between x and y, and β is a constant.

In general:

$$y_i = \beta x_i \tag{15}$$

The mean square error of y is:

$$M_y = \frac{1}{N} \sum_{i=1}^{N} \left[y_i - \beta x_i\right]^2$$

$$= \frac{1}{N} \sum_{i=1}^{N} \left[(y_i - \overline{y}) - \beta\,(x_i - \overline{x}) + (\overline{y} - \beta\,\overline{x})\right]^2$$

$$= \sigma_y^2 + \beta^2\,\sigma_x^2 - 2\,\beta\rho\,\sigma_y\,\sigma_x + (\overline{y} - \beta\overline{x})^2 \tag{16}$$

Differentiating with respect to β and setting the result equal to zero:

$$\beta = \frac{\rho\sigma_y\sigma_x + \bar{x}\,\bar{y}}{\sigma_x^2 + \bar{x}^2} \tag{17}$$

Thus

$$y_i = \left[\frac{\rho\sigma_y\,\sigma_x + \bar{x}\,\bar{y}}{\sigma_x^2 + \bar{x}^2}\right] x_i \tag{18}$$

Comparing the coefficients in Equations (14a) and (17) for the 6-hour data at 30,000 ft. (Table 4) where the average persistence correlation is seen to be about 0.8, we find:

$$\left[\frac{1+r}{2}\right]^{\frac{1}{2}} = .95$$

From Table 4 the following values were computed:

ρ	=	.88	$\bar{x}$	=	25.33 kts
σ_x	=	5.01 kts	$\bar{y}$	=	23.36 kts
σ_y	=	4.91 kts			

Substituting these values into (17):

$$\beta = .92$$

Thus it is evident that Equations (14a) and (18) are essentially identical in this case. As a final check the standard error of estimate, SE, was computed for both equations, using Equation (16) (i.e. $SE^2 = M_y$) with the appropriate value of β. For Equation (14a) SE = 2.5 kts; for Equation (18) SE = 2.4 kts.

The foregoing analysis indicates that the assumption of a linear relation between the forecast wind and the existing wind at forecast time is indeed valid. Furthermore the relationship is a strong one, accounting for all but 23% of the random variabiaity of RF for 6-hour forecasts at 30,000 feet. However, one additional point should be taken into consideration, namely the fact that RF tends to be greater than RP for values of RP less than about 20 kts. In an attempt to account for this behavior the form of Equation (15) was expanded to include a constant term, a:

$$y_i = a + b\,x_i \tag{19}$$

Again applying least squares the constants are found to be

$$a = \bar{y} - \rho \frac{\sigma_y}{\sigma_x} \bar{x}$$

$$b = \rho \frac{\sigma_y}{\sigma_x}$$

where the symbols are the same as in Equation (18).

Initially, four linear regression equations of the form (19) were developed from the data in Tables 4 and 5, one for each level and forecast period.

The results were as follows:

Forecast period, hrs.	6	6	12	12
Level, Kft	30	40	30	40
Number of cases	35	35	29	29
a	1.58	3.45	3.88	3.86
b	0.86	0.81	0.76	0.79
ρ	0.88	0.84	0.95	0.84
Standard error, kts	2.4	1.8	2.2	1.9

It is apparent that the four equations are sufficiently similar to warrant combining all the data into a single equation. The resulting relation is:

$$RF = 3.96 + 0.773RP \tag{20}$$

for which the number of cases is 128, $\rho = .93$ and the standard error of estimate is 2.0 kts. This equation accounts for all but 14% of the random variability of RF for all levels, seasons and forecast periods. Solving (20) we find $RF \geq RP$ when $RP \leq 17.2$ which agrees very well with the data*.

4.2 Persistence Errors for a Five Year Sample

We have seen that Equation (20) provides a reliable estimate of the root mean square forecast error, RF, once the persistence error, RP, is known. Equation (11) expresses RP as a function of the standard vector deviation of

* In Tables 4 and 5 the seasonal value of RP is found to be less than or equal to 17.2 kts in 9 cases. For 7 of those cases $RF \geq RP$.

the wind, σ, and the persistence coefficient, r. In a recent publication Charles (1959, 1960) has tabulated values of σ and 24-hour persistence correlation for 15 levels from 950 to 10 mb at 51 stations on a monthly and seasonal basis for the five-year period, 1953-58. From these data it is possible to compute persistence errors for a large number of stations.

Accordingly, seasonal values of RP were computed for the 300- and 200-mb levels (approximately 30K and 40K feet) for the 50 stations listed in Table 6. As before, the forecast periods considered were 6 and 12 hours. The appropriate persistence correlations were derived from the 24-hour values by the well known exponential relation:

$$r_t = e^{-kt} \tag{21}$$

where r_t is the persistence correlation at time t, and k is a constant.

At each station and level this equation was solved for k by substituting r_{24}. That value of k was then used to calculate r_6 and r_{12}. Having computed RP the corresponding RF was then determined from Equation (20).

4.3 Generalized Seasonal Statistics on Short Period Forecast Errors

We are now in a position to examine quantitatively, two fundamental questions which arise in connection with the short-period wind prediction problem:

(1) As a forecast technique, what advantage does short-period persistence offer in comparison with climatology? In other words, by what amount is the present wind a better estimator than the climatic mean wind?

(2) What advantage, if any, does a subjective forecast have over persistence?

In answering Question (1) it is convenient to measure the improvement of persistence over climatology by means of the percent reduction in variance, RVP. By definition:

$$RVP = 100 \left[1 - \frac{MP}{\sigma^2} \right] \tag{22}$$

Table 6. Stations for which Seasonal Persistence Errors were Computed (Charles 1959, 1960)

Index No.	Station	Index No.	Station
200	Nome, Alaska	445	Columbia, Mo.
265	Fairbanks, Alaska	531	Rantoul
273	Anchorage, Alaska	429	Dayton
964	Whitehorse, Yukon	520	Pittsburgh
398	Annette, Alaska	405	Washington, D. C.
879	Edmonton, Alberta	503	Hempstead, N. Y.
793	Seattle	506	Nantucket
747	International Falls	297	Long Beach
681	Boise	365	Albuquerque
775	Great Falls	259	Fort Worth
764	Bismarck	340	Little Rock
655	St. Cloud	327	Nashville
645	Green Bay	317	Greensboro
734	Sault Ste.Marie	308	Norfolk NAS
537	Mt. Clemens	208	Charleston, S. C.
528	Buffalo	274	Tucson
722	Maniwaki, Quebec	265	Big Springs
	Rome	240	Lake Charles
712	Caribou	232	Burrwood
597	Medford	226	Montgomery
493	Oakland	206	Jacksonville
486	Ely	250	Brownsville
469	Denver	202	Miami
451	Dodge City	525	San Juan, P. R.
553	Omaha	806	Albrook, C. Z.

Question (2) may be answered in terms of an index called the forecast advantage, FA, which is expressed as follows:

Let RVF be the percent reduction in variance of subjective forecasts with respect to climatology.
Then

$$FA = RVF - RVP$$

$$= 100 \left[\left(1 - \frac{MF}{\sigma^2} \right) - \left(1 - \frac{MP}{\sigma^2} \right) \right]$$

$$= 100 \left[\frac{MP - MF}{\sigma^2} \right] \qquad (23)$$

Thus we see that FA measures the residual improvement which subjective forecasts register over persistence after the advantage of persistence over climatology has been accounted for.

Tables 7 and 8 contain the generalized seasonal statistics on short-period forecast errors at 300 and 200 mb based on the methods developed in this paper. Quantities tabulated are:

σ	(Charles, 1959)
RP	Equation (11)
RF	Equation (20)
r	(Charles, 1960) plus Equation (21)
RVP	Equation (22)
FA	Equation (23). Whenever $RF \geq RP$ the value

of FA is entered as zero.

INDEX TO TABLES 7 AND 8

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors.

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors.

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors

σ standard vector deviation of the wind.

RP root mean square error of persistence forecasts.

RF root mean square error of subjective forecasts.

r six-hour persistence correlation.

RVP percent reduction in variance of persistence forecasts with respect to climatology.

FA forecast advantage over persistence.

NOME, ALASKA (200)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	39.6	21.0	20.2	.86	72	2.0
	200	33.0	14.5	15.2	.90	81	0
Spring	300	37.4	20.9	20.1	.84	69	2.3
	200	27.4	14.0	14.8	.87	74	0
Summer	300	38.0	20.5	19.8	.85	71	1.9
	200	29.7	14.3	15.0	.89	77	0
Fall	300	39.4	23.2	21.9	.83	65	3.8
	200	30.6	15.6	16.0	.87	74	0

FAIRBANKS, ALASKA (265)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	42.3	22.8	21.6	.85	71	2.9
	200	34.7	15.3	15.8	.90	81	0
Spring	300	35.1	21.1	20.3	.82	64	2.7
	200	26.4	12.1	13.3	.90	79	0
Summer	300	35.1	19.7	19.2	.84	68	1.5
	200	27.0	13.0	14.0	.89	77	0
Fall	300	38.8	23.3	22.0	.82	64	3.9
	200	30.4	14.6	15.3	.89	77	0

ANCHORAGE, ALASKA (273)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	46.0	25.8	23.9	.84	68	4.4
	200	36.9	17.0	17.1	.90	79	0
Spring	300	39.0	22.6	21.4	.84	67	3.5
	200	29.1	14.3	15.0	.88	76	0
Summer	300	38.6	20.5	19.8	.86	72	1.8
	200	31.0	14.3	15.0	.90	79	0
Fall	300	43.6	26.2	24.7	.82	64	5.3
	200	34.5	18.3	18.1	.86	72	0.6

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

WHITEHORSE, YUKON (964)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	43.8	25.8	23.9	.83	65	4.8
	200	35.0	17.2	17.3	.89	77	0
Spring	300	41.9	23.5	22.1	.84	69	3.6
	200	31.0	15.2	15.7	.88	76	0
Summer	300	34.7	18.7	18.4	.85	70	0.8
	200	28.3	13.9	14.7	.88	76	0
Fall	300	40.4	23.8	22.4	.83	65	4.1
	200	35.7	18.2	18.0	.87	74	0.6

ANNETTE, ALASKA (398)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	46.0	28.1	25.7	.81	62	6.0
	200	37.8	20.4	19.7	.85	70	2.0
Spring	300	46.9	23.9	22.4	.87	74	3.2
	200	35.3	18.0	17.9	.87	74	0.3
Summer	300	42.1	22.3	21.2	.86	72	2.6
	200	34.5	16.6	16.8	.89	77	0
Fall	300	44.6	26.8	24.7	.82	64	5.4
	200	40.4	22.6	21.4	.84	69	3.2

EDMONTON, ALBERTA (879)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	39.4	27.2	25.0	.76	53	7.3
	200	31.0	17.7	17.6	.84	67	0.4
Spring	300	41.7	25.4	23.6	.81	62	5.1
	200	29.7	16.0	16.3	.85	70	0
Summer	300	36.7	24.2	22.7	.78	56	5.2
	200	32.8	17.7	17.6	.85	70	0.3
Fall	300	41.9	27.7	25.4	.78	56	7.0
	200	37.6	22.2	21.1	.83	65	3.4

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

SEATTLE (793)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	54.3	34.8	30.9	.80	59	8.7
	200	42.7	25.2	23.5	.83	65	4.5
Spring	300	53.9	30.7	27.7	.84	67	6.0
	200	40.0	21.6	20.7	.85	70	2.4
Summer	300	43.4	25.6	23.8	.83	65	4.8
	200	39.2	19.2	18.8	.88	76	1.0
Fall	300	52.4	30.9	27.9	.83	65	6.4
	200	46.0	25.8	23.9	.84	68	4.5

INTERNATIONAL FALLS (747)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	47.5	30.9	27.8	.79	57.	7.8
	200	38.4	19.6	19.1	.87	74	1.3
Spring	300	45.8	29.3	26.6	.80	60	7.2
	200	37.0	22.2	21.1	.82	64	3.5
Summer	300	39.6	22.2	21.1	.84	69	2.9
	200	41.9	22.6	21.4	.85	70	3.0
Fall	300	51.0	32.6	29.2	.80	59	8.1
	200	43.8	26.7	24.6	.81	62	5.6

BOISE (681)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	45.6	29.2	26.5	.80	59	7.0
	200	39.4	22.5	21.3	.84	67	3.4
Spring	300	46.0	27.6	25.3	.82	64	7.6
	200	38.6	20.8	20.0	.85	70	2.2
Summer	300	32.6	19.6	19.1	.82	64	1.7
	200	33.8	17.9	17.8	.86	72	0.3
Fall	300	45.0	28.4	25.9	.80	61	6.7
	200	43.3	24.2	22.7	.84	68	3.6

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
GREAT FALLS (775)							
Winter	300	49.5	34.6	30.7	.76	51	10.3
	200	38.8	23.7	22.3	.81	62	4.3
Spring	300	46.2	27.3	25.1	.83	65	5.4
	200	36.7	19.5	19.0	.86	72	1.4
Summer	300	36.7	19.8	19.3	.85	70	1.5
	200	37.6	19.2	18.8	.87	74	1.1
Fall	300	47.9	29.2	25.4	.81	62	9.0
	200	42.7	23.9	22.4	.84	69	3.8
BISMARCK (764)							
Winter	300	44.0	26.8	24.7	.81	62	5.6
	200	35.3	18.7	18.4	.86	72	0.9
Spring	300	43.1	24.6	23.0	.84	67	4.1
	200	37.2	19.0	18.7	.87	74	0.8
Summer	300	33.8	19.3	18.9	.84	67	1.3
	200	36.7	18.7	18.4	.87	74	0.8
Fall	300	44.8	27.3	25.1	.81	62	5.7
	200	41.3	22.3	21.2	.85	70	2.8
ST. CLOUD (655)							
Winter	300	47.3	28.9	26.3	.81	62	6.3
	200	38.8	19.0	18.7	.88	76	0.8
Spring	300	44.6	26.8	24.7	.82	64	5.4
	200	37.4	20.2	19.6	.85	70	1.7
Summer	300	35.3	18.7	18.4	.86	72	0.8
	200	37.8	19.3	18.9	.87	74	1.1
Fall	300	45.6	27.8	25.5	.81	62	5.9
	200	43.4	23.0	21.7	.86	72	3.1

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
			GREEN BAY (645)				
Winter	300	50.6	30.4	27.5	.82	64	6.6
	200	43.1	22.0	21.0	.87	74	2.3
Spring	300	45.2	27.6	25.3	.81	62	6.0
	200	40.4	22.6	21.4	.84	69	3.2
Summer	300	35.9	19.4	19.0	.85	70	1.2
	200	38.2	20.6	19.9	.85	70	1.9
Fall	300	46.4	27.8	25.4	.82	64	5.9
	200	43.4	23.4	22.0	.85	70	3.4
			SAULT STE. MARIE (734)				
Winter	300	53.4	32.6	29.2	.81	62	7.4
	200	45.0	25.2	23.4	.84	69	4.3
Spring	300	47.9	30.2	27.3	.80	61	7.3
	200	41.1	23.0	21.7	.84	69	3.4
Summer	300	39.2	23.1	21.8	.83	65	3.7
	200	42.9	23.2	21.9	.85	70	3.2
Fall	300	50.0	31.5	28.3	.80	61	7.7
	200	46.0	26.2	24.2	.84	67	4.8
			MT. CLEMENS (537)				
Winter	300	54.9	35.7	31.6	.79	57	9.1
	200	45.4	24.5	22.9	.85	70	3.7
Spring	300	48.1	30.3	27.4	.80	61	7.2
	200	44.0	26.0	24.1	.83	65	4.9
Summer	300	35.9	21.5	20.6	.82	64	2.9
	200	41.7	22.5	21.4	.85	70	2.8
Fall	300	46.8	30.0	27.2	.80	59	7.3
	200	44.6	26.3	24.3	.83	65	5.1

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

BUFFALO (528)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	52.2	33.9	30.2	.79	57	8.7
	200	44.6	24.1	22.6	.85	70	3.5
Spring	300	47.9	30.7	27.7	.80	59	7.6
	200	42.5	24.2	22.7	.84	67	3.9
Summer	300	35.9	20.5	19.8	.84	67	2.7
	200	41.1	21.8	20.8	.86	72	2.5
Fall	300	46.0	27.6	25.3	.82	64	5.8
	200	42.9	24.5	22.9	.84	67	4.1

MANIWAKI, QUEBEC (722)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	50.6	33.4	29.8	.78	56	8.8
	200	43.4	23.4	22.0	.85	70	3.4
Spring	300	48.7	30.7	27.7	.80	61	7.4
	200	41.9	22.6	21.4	.85	70	3.0
Summer	300	38.6	22.8	21.6	.83	65	3.5
	200	41.7	22.5	21.4	.85	70	2.8
Fall	300	46.2	29.1	26.4	.80	61	7.0
	200	43.6	25.7	23.8	.83	65	4.9

ROME

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	55.1	35.8	31.6	.79	58	9.2
	200	45.8	26.1	24.1	.84	67	4.8
Spring	300	49.7	32.3	28.9	.79	57	8.4
	200	46.6	28.4	25.9	.81	62	6.3
Summer	300	40.0	21.6	20.7	.85	70	2.4
	200	45.6	24.6	23.0	.85	70	3.7
Fall	300	48.9	29.3	26.6	.82	64	6.3
	200	46.4	26.4	24.4	.84	67	4.7

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

CARIBOU (712)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	56.6	36.2	31.9	.80	59	9.0
	200	47.3	25.5	23.7	.85	70	4.0
Spring	300	51.6	33.0	29.5	.80	59	8.2
	200	42.7	24.3	22.7	.84	67	4.1
Summer	300	42.1	26.5	24.4	.80	61	5.8
	200	43.1	24.6	23.0	.84	67	4.1
Fall	300	50.0	33.0	29.5	.78	56	8.8
	200	46.6	29.4	26.7	.80	61	7.0
MEDFORD (597)							
Winter	300	51.0	31.1	28.0	.81	63	7.0
	200	42.9	23.2	21.9	.85	70	3.2
Spring	300	47.3	27.9	25.5	.83	65	5.7
	200	41.1	23.0	21.7	.84	69	3.4
Summer	300	37.8	21.5	20.6	.84	67	2.6
	200	37.2	19.0	18.6	.87	74	1.1
Fall	300	47.9	26.8	24.7	.84	69	4.7
	200	44.8	22.8	21.6	.87	74	2.7
OAKLAND (493)							
Winter	300	51.2	28.7	26.1	.84	69	5.3
	200	46.9	23.9	22.4	.87	74	3.2
Spring	300	46.9	26.3	24.3	.84	69	4.6
	200	41.1	22.2	21.1	.85	70	2.8
Summer	300	33.0	17.5	17.5	.86	72	0
	200	34.9	17.1	17.2	.88	76	0
Fall	300	46.0	24.8	23.1	.85	70	3.8
	200	44.0	22.4	21.3	.87	74	2.5

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

ELY (486)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	48.7	29.2	26.5	.82	64	6.2
	200	43.1	22.8	21.6	.86	72	2.9
Spring	300	45.8	26.1	24.1	.84	67	4.7
	200	40.7	22.8	21.6	.84	69	3.2
Summer	300	29.5	16.8	17.0	.84	67	0
	200	31.6	15.5	15.9	.88	76	0
Fall	300	43.1	25.4	23.6	.83	65	4.7
	200	41.7	22.5	21.4	.85	70	2.8

DENVER (469)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	51.2	30.7	27.7	.82	64	6.6
	200	46.4	24.6	23.0	.86	72	3.5
Spring	300	45.0	28.8	26.2	.80	60	7.1
	200	43.6	23.5	22.1	.85	70	3.4
Summer	300	28.5	14.5	15.2	.87	74	0
	200	32.8	15.1	15.6	.8[illegible]	79	0
Fall	300	42.1	25.7	23.8	.81	62	5.3
	200	43.6	23.5	22.1	.85	70	3.4

DODGE CITY (451)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	50.4	31.5	28.3	.80	61	7.[illegible]
	200	44.8	22.8	21.6	.87	74	2.7
Spring	300	43.3	25.5	23.7	.83	65	4.7
	200	41.9	21.4	20.5	.87	74	2.1
Summer	300	26.0	13.3	14.2	.87	74	0
	200	30.3	14.5	15.2	.89	77	0
Fall	300	42.7	23.9	22.4	.84	69	3.8
	200	43.1	23.3	22.0	.85	70	3.2

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

OMAHA (553))

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	51.6	33.0	29.5	.80	59	8.2
	200	45.4	24.1	22.6	.86	72	3.4
Spring	300	47.5	27.1	24.9	.84	67	5.1
	200	44.2	22.5	21.4	.87	74	2.5
Summer	300	29.1	15.7	16.1	.85	70	0
	200	34.0	18.0	17.9	.86	72	0.3
Fall	300	46.4	28.3	25.8	.81	62	6.3
	200	43.6	23.5	22.1	.85	70	3.4
COLUMBIA, MISSOURI (445)							
Winter	300	55.1	33.6	29.9	.81	62	7.6
	200	50.2	26.6	21.5	.86	72	9.7
Spring	300	46.4	26.4	24.4	.84	67	4.7
	200	44.6	23.6	22.2	.86	72	3.2
Summer	300	28.5	15.1	15.6	.86	72	0
	200	32.4	17.5	17.5	.85	70	0
Fall	300	43.6	25.7	23.8	.83	65	5.0
	200	43.1	23.3	22.0	.85	70	3.2
RANTOUL (531)							
Winter	300	54.3	33.1	29.6	.81	62	7.5
	200	48.3	25.6	23.8	.86	72	3.8
Spring	300	46.9	29.4	26.8	.80	61	6.9
	200	45.0	25.2	23.5	.84	69	4.1
Summer	300	30.1	17.2	17.3	.84	67	0
	200	36.1	20.6	19.9	.84	67	2.2
Fall	300	44.6	27.2	25.0	.81	62	5.8
	200	43.6	24.4	22.8	.84	69	7.6

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

DAYTON (429)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	56.1	35.3	31.2	.80	60	8.5
	200	50.0	28.0	25.6	.84	69	5.1
Spring	300	46.0	24.8	23.1	.85	70	3.8
	200	43.6	25.7	23.8	.83	65	4.9
Summer	300	31.8	18.1	18.0	.84	67	0
	200	36.7	20.9	20.1	.84	67	2.4
Fall	300	43.1	29.3	26.6	.77	54	8.1
	200	42.7	24.3	22.7	.84	67	4.1

PITTSBURGH (520)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	54.1	35.7	31.6	.78	56	9.4
	200	47.9	28.7	26.2	.82	64	6.0
Spring	300	48.3	30.4	27.5	.80	61	7.2
	200	45.8	26.1	24.1	.84	67	4.8
Summer	300	34.0	19.4	19.0	.84	67	1.4
	200	40.4	21.8	20.8	.85	70	2.6
Fall	300	46.8	30.0	27.2	.80	79	7.3
	200	43.8	24.5	22.9	.84	69	4.0

WASHINGTON (405)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	53.2	34.6	30.7	.79	58	8.9
	200	45.6	26.9	24.8	.83	65	5.2
Spring	300	46.0	28.1	25.7	.81	62	6.1
	200	46.8	26.7	24.6	.84	67	4.9
Summer	300	34.9	17.8	17.7	.87	74	0.2
	200	40.4	19.8	19.3	.88	76	1.2
Fall	300	44.6	26.3	24.3	.83	65	5.1
	200	44.2	23.4	22.1	.86	72	3.0

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

HEMPSTEAD (503)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	56.8	38.6	33.8	.77	54	10.7
	200	46.4	29.2	26.5	.80	61	7.0
Spring	300	49.1	30.0	27.2	.81	62	6.6
	200	44.6	26.8	24.7	.82	64	5.4
Summer	300	38.0	21.3	20.4	.84	69	2.4
	200	42.9	22.7	21.5	.86	72	2.9
Fall	300	49.3	30.1	27.2	.81	62	6.8
	200	49.8	26.9	24.8	.85	70	4.4

NANTUCKET (506)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	57.6	37.4	32.9	.79	57	9.5
	200	49.5	29.7	26.9	.82	64	6.5
Spring	300	48.9	29.8	27.0	.81	62	6.7
	200	44.4	24.9	23.2	.84	69	4.1
Summer	300	39.8	21.5	20.6	.85	70	2.4
	200	43.4	23.0	21.7	.86	72	3.1
Fall	300	47.9	28.7	26.2	.82	64	6.0
	200	48.7	26.3	24.3	.85	70	4.3

LONG BEACH (297)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	47.3	26.5	24.4	.84	69	4.6
	200	46.9	23.9	22.4	.87	74	3.2
Spring	300	42.7	25.2	23.4	.83	65	4.8
	200	41.7	22.1	21.0	.86	72	2.7
Summer	300	26.0	12.5	13.6	.89	77	0
	200	30.1	13.8	14.6	.90	79	0
Fall	300	36.5	20.8	20.0	.84	67	2.4
	200	36.7	19.5	19.0	.86	72	1.4

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
ALBUQUERQUE (365)							
Winter	300	44.8	26.9	24.8	.82	64	5.4
	200	42.7	23.1	21.8	.85	70	3.1
Spring	300	40.7	25.6	23.8	.80	61	5.4
	200	39.0	21.8	20.8	.84	69	2.8
Summer	300	24.2	11.6	12.9	.89	77	0
	200	29.5	13.6	14.7	.90	79	0
Fall	300	36.5	20.4	19.7	.84	69	2.0
	200	40.7	20.8	20.0	.87	74	1.9
FORT WORTH (259)							
Winter	300	45.0	27.0	24.8	.81	62	5.5
	200	43.6	23.5	22.1	.85	70	3.3
Spring	300	41.3	22.3	21.2	.85	70	2.8
	200	43.3	23.4	22.0	.85	70	3.3
Summer	300	23.3	11.4	12.8	.88	76	0
	200	29.3	14.1	14.9	.89	77	0
Fall	300	37.4	20.2	19.6	.85	70	1.8
	200	40.0	19.6	19.1	.88	76	1.2
LITTLE ROCK (340)							
Winter	300	45.6	26.0	24.1	.84	67	4.6
	200	44.4	24.0	22.5	.85	70	3.5
Spring	300	41.1	23.4	22.1	.84	67	3.6
	200	43.6	21.4	20.5	.88	76	2.0
Summer	300	25.8	12.6	13.7	.88	76	0
	200	30.4	14.6	15.2	.89	77	0
Fall	300	38.6	19.7	19.2	.87	74	1.3
	200	40.0	20.4	19.7	.87	74	1.7

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

NASHVILLE (327)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	44.4	27.1	24.9	.82	64	5.7
	200	42.7	14.3	15.0	.84	67	0
Spring	300	43.3	23.4	22.1	.85	70	3.3
	200	44.6	21.9	20.9	.88	76	2.2
Summer	300	26.6	14.4	15.1	.85	70	0
	200	32.4	16.5	16.7	.87	74	0
Fall	300	39.2	23.9	22.4	.82	64	4.4
	200	40.2	22.9	21.7	.84	67	3.4

GREENSBORO (317)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	45.4	29.5	26.8	.79	58	7.4
	200	41.7	25.4	23.6	.81	62	5.1
Spring	300	42.5	24.2	22.7	.84	67	3.9
	200	43.6	23.1	21.8	.86	62	3.1
Summer	300	28.5	16.0	16.3	.84	68	0
	200	33.8	16.6	16.8	.88	76	0
Fall	300	40.4	23.0	21.7	.84	67	3.6
	200	40.5	19.8	19.3	.88	76	1.2

NORFOLK (308)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	50.4	32.3	28.9	.80	59	8.0
	200	45.6	27.4	25.1	.82	64	5.8
Spring	300	45.0					
	200	44.6					
Summer	300	32.4					
	200	38.6					
Fall	300	44.0					
	200	45.0					

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

CHARLESTON, S. C. (208)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	40.4	25.5	23.7	.80	61	5.4
	200	39.0	23.8	22.4	.81	62	4.3
Spring	300	41.3	21.9	20.9	.86	72	2.5
	200	44.2	22.5	21.4	.87	74	2.5
Summer	300	26.6	14.4	15.1	.85	70	0
	200	33.2	16.9	17.0	.87	74	0
Fall	300	40.0	21.2	20.4	.86	72	2.1
	200	42.1	19.4	19.0	.90	79	0.9

TUCSON (274)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	46.9	21.6	20.7	.90	79	1.8
	200	46.9	19.2	18.8	.91	83	0.7
Spring	300	41.9	25.1	23.4	.82	64	4.7
	200	41.3	21.9	20.9	.86	72	2.5
Summer	300	23.7	14.2	14.9	.82	64	0
	200	28.7	15.2	15.7	.86	72	0
Fall	300	35.3	19.1	18.7	.85	70	1.2
	200	38.6	18.9	18.6	.88	76	0.8

BIG SPRING (265)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	42.9	23.2	21.9	.85	70	3.1
	200	41.3	20.2	19.6	.88	76	1.4
Spring	300	37.4	19.8	19.3	.86	72	1.4
	200	39.2	20.8	20.0	.86	72	2.1
Summer	300	23.3	13.7	14.6	.83	65	0
	200	29.7	16.6	16.8	.84	69	0
Fall	300	34.5	17.6	17.6	.87	74	0
	200	38.4	18.4	18.2	.89	77	0.5

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

LAKE CHARLES (240)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	39.6	20.2	19.6	.87	74	1.5
	200	40.4	19.8	19.3	.88	76	1.2
Spring	300	37.6	20.3	19.7	.85	70	1.8
	200	40.9	19.6	19.1	.89	77	1.2
Summer	300	23.5	14.1	14.9	.82	64	0
	200	30.8	16.6	16.8	.85	70	0
Fall	300	36.5	17.5	17.5	.89	77	0
	200	39.4	18.9	18.6	.89	77	0.7

BURRWOOD (232)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	37.4	20.2	19.6	.85	70	1.7
	200	39.6	19.0	18.7	.89	77	0.7
Spring	300	35.3	17.3	17.3	.88	76	0
	200	39.2	18.8	18.5	.89	77	0.7
Summer	300	22.5	12.2	13.4	.85	70	0
	200	28.9	16.2	16.5	.84	69	0
Fall	300	34.9	16.8	17.0	.89	77	0
	200	38.8	17.8	17.7	.90	79	0.2

MONTGOMERY (226)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	44.4	21.3	20.4	.89	77	1.7
	200	44.6	20.5	19.8	.90	79	1.4
Spring	300	42.9	25.3	23.5	.83	65	4.8
	200	47.5	23.3	22.0	.88	76	2.6
Summer	300	24.6	14.8	15.4	.82	64	0
	200	32.4	18.5	18.3	.84	67	0.7
Fall	300	41.7	20.4	19.7	.88	76	1.6
	200	44.2	21.2	20.4	.89	77	1.7

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

JACKSONVILLE (206)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	40.0	20.4	19.7	.87	74	1.6
	200	41.9	20.1	19.5	.89	77	1.4
Spring	300	38.8	17.8	17.7	.90	79	0.2
	200	45.2	19.9	19.3	.90	81	1.2
Summer	300	22.1	10.8	12.3	.88	76	0
	200	29.3	12.9	13.9	.90	81	0
Fall	300	37.2	17.1	17.2	.90	79	0
	200	41.1	18.1	18.0	.90	81	0.2
BROWNSVILLE (250)							
Winter	300	34.3	18.2	18.0	.86	72	0.5
	200	38.6	18.9	18.6	.88	76	0.8
Spring	300	29.5	15.9	16.2	.85	70	0
	200	33.6	17.8	17.7	.86	72	0.3
Summer	300	20.0	10.2	11.8	.87	74	0
	200	27.9	14.2	14.9	.87	74	0
Fall	300	31.0	14.9	15.5	.89	77	0
	200	35.5	15.6	16.0	.90	81	0
MIAMI (202)							
Winter	300	37.2	18.2	18.0	.88	76	0.5
	200	37.0	19.6	19.1	.86	72	1.4
Spring	300	33.0	15.8	16.2	.89	77	0
	200	38.2	18.3	18.1	.89	77	0.5
Summer	300	19.2	10.4	12.0	.85	70	0
	200	28.7	14.1	14.9	.88	76	0
Fall	300	32.2	14.2	14.9	.90	81	0
	200	39.4	17.3	17.3	.90	81	0

Table 7. Seasonal Wind Statistics and Derived Six-Hour Forecast Errors (continued)

SAN JUAN, P. R.

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	27.7	13.6	14.5	.88	76	0
	200	29.9	14.7	15.3	.88	76	0
Spring	300	23.9	11.5	12.8	.89	77	0
	200	29.1	14.3	15.0	.88	76	0
Summer	300	16.7	9.5	11.3	.84	67	0
	200	23.5	12.0	13.2	.87	74	0
Fall	300	22.1	10.8	12.3	.88	76	0
	200	30.1	13.8	14.6	.90	79	0

ALBROOK, C. Z. (806)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	21.5	10.3	11.9	.89	77	0
	200	26.6	13.0	14.0	.88	76	0
Spring	300	18.0	8.3	10.4	.90	79	0
	200	23.1	11.1	12.5	.89	77	0
Summer	300	11.2	8.2	10.3	.73	47	0
	200	18.2	12.6	13.7	.76	53	0
Fall	300	13.4	7.9	10.1	.83	65	0
	200	19.8	10.1	11.8	.87	74	0

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors

σ	standard vector deviation of the wind.
RP	root mean square error of persistence forecasts.
RF	root mean square error of subjective forecasts.
r	six-hour persistence correlation.
RVP	percent reduction in variance of persistence forecasts with respect to climatology.
FA	forecast advantage over persistence.

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
NOME, ALASKA (200)							
Winter	300	39.6	28.5	26.0	.74	48	8.7
	200	33.0	19.8	19.3	.82	64	1.8
Spring	300	37.4	28.0	25.6	.72	44	9.2
	200	27.4	18.9	18.6	.76	53	1.5
Summer	300	38.0	28.1	25.7	.73	45	8.9
	200	29.7	19.6	19.1	.78	56	2.2
Fall	300	39.4	31.1	28.0	.68	73	11.8
	200	30.6	21.4	20.5	.76	51	4.0
FAIRBANKS, ALASKA (265)							
Winter	300	42.3	30.9	27.9	.73	47	9.9
	200	34.7	21.2	20.4	.81	62	2.8
Spring	300	35.1	28.4	25.9	.67	34	11.0
	200	26.4	16.6	16.8	.80	61	0
Summer	300	35.1	26.3	24.3	.72	44	8.2
	200	27.0	17.6	17.6	.79	57	0
Fall	300	38.8	31.4	28.2	.67	34	12.7
	200	30.4	20.1	19.5	.78	56	2.6
ANCHORAGE, ALASKA (273)							
Winter	300	46.0	35.0	31.0	.71	42	12.5
	200	36.9	23.2	21.9	.80	61	4.3
Spring	300	39.0	30.0	27.2	.70	41	10.5
	200	29.1	19.8	19.3	.77	54	2.3
Summer	300	38.6	28.2	25.8	.73	47	8.7
	200	31.0	19.5	19.0	.80	61	2.0
Fall	300	43.6	35.8	31.6	.66	33	14.9
	200	34.5	24.8	23.1	.74	48	6.9

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
WHITEHORSE, YUKON (964)							
Winter	300	43.8	34.6	30.7	.68	37	13.2
	200	25.9	23.3	22.0	.79	57	4.6
Spring	300	41.9	31.4	28.2	.72	44	10.9
	200	31.0	20.5	19.8	.78	56	2.9
Summer	300	34.7	26.0	24.1	.72	44	7.9
	200	28.3	19.2	18.8	.77	54	1.9
Fall	300	40.4	31.9	28.6	.69	38	12.2
	200	35.7	24.6	23.0	.76	53	6.0
ANNETTE, ALASKA (398)							
Winter	300	46.0	38.2	33.5	.66	31	15.8
	200	37.8	28.0	25.6	.73	45	9.0
Spring	300	46.9	33.3	29.7	.75	50	10.3
	200	35.3	24.4	22.8	.76	53	6.1
Summer	300	42.1	30.3	27.4	.74	48	9.4
	200	34.5	22.8	21.6	.78	56	4.5
Fall	300	44.6	36.6	32.3	.66	33	14.9
	200	40.4	30.3	27.4	.72	44	10.3
EDMONTON, ALBERTA (879)							
Winter	300	39.4	36.2	31.9	.58	15	19.9
	200	31.0	24.2	22.7	.70	40	7.3
Spring	300	41.7	35.0	31.0	.65	30	15.2
	200	29.7	21.7	20.7	.73	47	4.8
Summer	300	36.7	32.7	29.2	.61	21	16.1
	200	32.8	24.6	23.0	.72	44	7.1
Fall	300	41.9	36.9	32.5	.61	23	17.4
	200	37.6	29.7	26.9	.68	37	11.2

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

SEATTLE (793)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	54.3	46.7	40.1	.63	26	19.4
	200	42.7	33.7	30.0	.68	37	12.9
Spring	300	53.9	41.5	36.0	.70	41	14.7
	200	40.0	29.6	26.8	.73	45	9.9
Summer	300	43.4	34.3	30.5	.68	37	13.1
	200	39.2	27.0	24.8	.76	47	7.4
Fall	300	52.4	41.4	36.0	.68	37	15.2
	200	46.0	35.4	31.3	.70	41	12.9

INTERNATIONAL FALLS (747)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	47.5	41.3	35.9	.62	25	18.5
	200	38.4	26.9	24.8	.76	51	7.4
Spring	300	45.8	38.9	34.1	.64	28	16.7
	200	37.0	30.0	27.2	.67	34	11.7
Summer	300	39.6	30.1	27.2	.71	42	10.6
	200	41.9	31.0	27.9	.73	45	10.4
Fall	300	51.0	43.9	37.9	.63	26	18.7
	200	43.8	36.8	32.4	.65	30	15.9

BOISE (681)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	45.6	39.7	34.7	.62	25	17.9
	200	39.4	30.3	27.4	.70	41	10.8
Spring	300	46.0	37.7	33.1	.66	33	15.4
	200	38.6	28.2	25.8	.73	47	8.7
Summer	300	32.6	26.4	24.4	.67	34	9.6
	200	33.8	24.3	22.7	.74	48	6.6
Fall	300	45.0	37.8	33.2	.65	30	16.1
	200	43.3	32.9	29.4	.71	42	11.6

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
GREAT FALLS (775)							
Winter	300	49.5	46.0	39.5	.57	13	22.7
	200	38.8	32.2	28.9	.66	31	13.4
Spring	300	46.2	37.0	32.6	.68	35	14.3
	200	36.7	26.1	24.1	.75	50	7.5
Summer	300	36.7	27.5	25.2	.72	44	9.0
	200	37.6	26.3	24.3	.76	51	7.2
Fall	300	47.9	40.2	35.0	.65	30	17.0
	200	42.7	32.5	29.1	.71	42	11.5
BISMARCK (764)							
Winter	300	44.0	37.0	32.6	.65	30	15.8
	200	35.3	25.4	23.6	.74	48	7.1
Spring	300	43.1	33.6	29.9	.70	40	12.6
	200	37.2	26.0	24.1	.76	51	6.9
Summer	300	33.8	26.7	24.6	.69	38	9.4
	200	36.7	25.7	23.8	.76	51	7.0
Fall	300	44.8	37.6	33.0	.65	30	16.2
	200	41.3	31.0	27.9	.72	44	10.7
ST. CLOUD (655)							
Winter	300	47.3	39.3	34.3	.66	31	16.4
	200	38.8	26.4	24.4	.77	54	6.7
Spring	300	44.6	36.1	31.1	.67	34	17.5
	200	37.4	27.7	25.4	.73	45	8.7
Summer	300	35.3	25.4	23.6	.74	48	7.1
	200	37.8	26.8	24.7	.75	50	8.3
Fall	300	45.6	37.8	33.2	.66	31	15.7
	200	43.4	31.7	28.5	.73	47	10.2

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

GREEN BAY (645)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	50.6	41.0	35.6	.67	34	16.2
	200	43.1	30.6	27.6	.75	50	9.4
Spring	300	45.2	37.5	33.0	.66	31	15.5
	200	40.4	30.7	27.7	.71	42	10.7
Summer	300	35.9	26.6	24.5	.73	45	8.3
	200	38.2	28.6	26.1	.72	44	9.4
Fall	300	46.4	37.6	33.0	.67	34	15.1
	200	43.4	32.5	29.1	.72	44	11.1

SAULT ST. MARIE (734)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	53.4	43.8	37.8	.66	33	17.2
	200	45.0	34.6	30.7	.70	41	12.6
Spring	300	47.9	40.2	35.0	.64	29	17.0
	200	41.1	31.2	28.1	.71	42	10.9
Summer	300	39.2	31.4	28.2	.68	35	12.4
	200	42.9	31.3	28.2	.73	47	10.0
Fall	300	50.0	42.0	36.4	.64	29	17.6
	200	46.0	35.9	31.7	.70	40	13.4

MT CLEMENS (537)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	54.9	47.8	40.9	.62	25	20.3
	200	45.4	33.6	29.9	.73	45	11.4
Spring	300	48.1	40.4	35.2	.64	29	17.0
	200	44.0	34.8	30.9	.68	37	13.2
Summer	300	35.9	29.4	26.7	.66	33	11.8
	200	41.7	30.9	27.9	.73	45	10.1
Fall	300	46.8	40.7	35.4	.62	25	18.4
	200	44.6	35.7	31.6	.68	35	13.9

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

BUFFALO (528)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	52.2	45.9	39.4	.61	23	20.3
	200	44.6	33.4	29.8	.72	44	11.4
Spring	300	47.9	41.7	36.2	.62	25	18.7
	200	42.5	33.1	29.6	.70	39	12.1
Summer	300	35.9	27.6	25.3	.70	41	9.4
	200	41.1	29.6	26.8	.74	48	9.3
Fall	300	46.0	37.7	33.1	.66	33	15.4
	200	42.9	33.0	29.5	.70	41	11.9
MANIWAKI, QUEBEC (722)							
Winter	300	50.6	45.0	38.7	.61	21	20.6
	200	43.4	32.6	29.2	.72	44	11.2
Spring	300	48.7	41.4	36.0	.64	28	17.6
	200	41.9	31.0	27.9	.73	45	10.4
Summer	300	38.6	30.5	27.5	.68	37	11.7
	200	41.7	31.3	25.2	.72	44	19.8
Fall	300	46.2	39.3	34.3	.64	28	17.2
	200	43.6	34.4	30.6	.68	37	13.0
ROME							
Winter	300	55.1	48.5	41.4	.61	[illegible]	21.0
	200	45.8	35.3	31.2	.70	41	13.0
Spring	300	49.7	43.7	37.7	.61	23	19.8
	200	46.6	38.7	33.9	.66	31	16.0
Summer	300	40.0	29.2	26.5	.73	47	9.4
	200	45.6	33.7	30.0	[illegible]	45	11.3
Fall	300	48.9	39.1	[illegible]	[illegible]	[illegible]	15.0
	200	46.4	36.7	32.3	.69	38	14.1

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
			CARIBOU (712)				
Winter	300	56.6	48.7	41.6	.63	26	20.0
	200	47.3	35.5	31.4	.72	44	12.3
Spring	300	51.6	43.9	37.9	.64	28	18.4
	200	42.7	33.3	29.7	.70	40	12.4
Summer	300	42.1	35.4	31.3	.64	29	15.4
	200	43.1	33.6	29.9	.70	40	12.6
Fall	300	50.0	44.5	38.4	.61	21	20.2
	200	46.6	39.1	34.2	.64	29	16.5
			MEDFORD (597)				
Winter	300	51.0	42.3	36.7	.66	31	17.0
	200	42.9	31.7	28.5	.73	45	10.5
Spring	300	47.3	37.4	32.9	.68	37	14.1
	200	41.1	31.6	28.4	.71	41	11.4
Summer	300	37.8	29.9	27.1	.69	38	11.2
	200	37.2	26.4	24.4	.75	50	7.3
Fall	300	47.9	35.9	31.7	.72	44	12.4
	200	44.8	31.8	28.5	.75	50	9.9
			OAKLAND (493)				
Winter	300	51.2	38.9	34.0	.71	42	13.6
	200	46.9	32.4	29.0	.76	53	9.5
Spring	300	46.9	35.6	31.5	.71	42	12.5
	200	41.1	30.0	27.2	.73	47	9.5
Summer	300	33.0	23.8	22.4	.74	48	5.9
	200	34.9	23.0	21.7	.78	56	4.8
Fall	300	46.0	34.5	30.6	.72	44	12.0
	200	44.0	30.8	27.8	.76	51	9.1

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

ELY (486)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	48.7	39.9	34.8	.66	33	16.1
	200	43.1	31.0	27.9	.74	48	9.8
Spring	300	45.8	35.7	31.6	.70	40	13.2
	200	40.7	30.9	27.8	.71	42	11.0
Summer	300	29.5	22.7	21.5	.70	41	6.1
	200	31.6	21.5	20.6	.77	54	3.8
Fall	300	43.1	34.0	30.2	.68	37	13.1
	200	41.7	30.9	27.8	.73	45	10.5

DENVER (469)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	51.2	42.0	36.4	.66	29	16.7
	200	46.4	33.4	29.8	.74	48	10.6
Spring	300	45.0	39.2	34.3	.62	25	17.8
	200	43.6	31.8	28.5	.73	47	10.5
Summer	300	28.5	20.0	19.4	.76	51	2.9
	200	32.8	21.0	20.2	.80	59	3.1
Fall	300	42.1	34.9	30.9	.66	31	14.8
	200	43.6	31.8	28.5	.73	47	10.5

DODGE CITY (451)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	50.4	42.0	36.4	.64	29	17.6
	200	44.8	31.8	28.5	.75	50	9.9
Spring	300	43.3	34.2	30.4	.68	37	13.1
	200	41.9	29.7	26.9	.75	50	9.0
Summer	300	26.0	18.2	18.0	.76	51	1.1
	200	30.3	20.0	19.4	.78	56	2.6
Fall	300	42.7	32.5	29.1	.71	42	11.5
	200	43.1	31.9	28.6	.73	45	10.7

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

OMAHA (553)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	51.6	43.9	37.9	.64	28	18.4
	200	45.4	32.7	29.2	.74	48	10.5
Spring	300	47.5	37.5	33.0	.69	38	14.1
	200	44.2	30.9	27.8	.76	51	9.3
Summer	300	29.1	21.5	20.6	.73	45	4.5
	200	34.0	24.5	22.9	.74	48	6.6
Fall	300	46.4	38.0	33.3	.66	33	15.6
	200	49.5	32.9	29.4	.73	45	11.0

COLUMBIA, MISSOURI (445)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	55.1	45.2	38.9	.66	33	17.4
	200	50.2	36.1	31.9	.74	48	11.3
Spring	300	46.4	36.7	32.3	.69	38	14.1
	200	44.6	32.1	28.8	.74	48	10.1
Summer	300	28.5	20.5	19.8	.74	48	3.5
	200	32.4	24.3	22.7	.72	44	7.2
Fall	300	43.6	34.4	30.6	.68	37	13.0
	200	43.1	31.5	28.3	.73	47	10.3

RANTOUL (531)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	54.3	45.6	39.2	.65	30	18.4
	200	48.3	34.8	30.9	.74	48	11.0
Spring	300	46.9	39.4	34.4	.65	70	16.8
	200	45.0	34.2	30.4	.71	42	12.0
Summer	300	30.1	23.8	22.4	.69	38	7.1
	200	36.1	27.8	25.4	.70	41	9.8
Fall	300	44.6	36.6	32.2	.66	33	15.2
	200	43.6	33.6	29.9	.70	41	12.4

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

DAYTON (429)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	56.1	47.1	40.4	.64	29	18.6
	200	50.0	38.0	33.3	.71	42	13.4
Spring	300	46.0	33.6	30.0	.73	47	10.8
	200	43.6	34.4	30.6	.68	37	13.0
Summer	300	31.8	24.8	23.1	.70	40	8.1
	200	36.7	28.3	25.8	.70	41	10.0
Fall	300	43.1	38.8	34.0	.60	19	18.8
	200	42.7	33.7	30.0	.69	38	12.9

PITTSBURGH (520)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	54.1	48.1	41.1	.60	20	21.3
	200	47.9	38.3	33.6	.68	35	14.7
Spring	300	48.3	40.6	35.3	.64	29	17.2
	200	45.8	36.2	31.9	.69	38	14.0
Summer	300	34.0	26.9	24.7	.69	38	9.8
	200	40.4	29.9	27.1	.73	45	9.8
Fall	300	46.8	39.8	34.7	.64	28	17.3
	200	43.8	33.3	29.7	.71	42	11.8

WASHINGTON (405)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	53.2	46.3	39.8	.62	24	19.8
	200	45.6	36.5	32.2	.68	35	14.2
Spring	300	46.0	38.6	33.8	.65	30	16.4
	200	46.8	37.0	32.6	.69	38	14.0
Summer	300	34.9	24.4	22.8	.76	51	6.2
	200	40.4	27.9	25.5	.76	53	7.9
Fall	300	44.6	35.2	31.2	.68	37	13.4
	200	44.2	33.6	29.9	.74	48	12.0

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

HEMPSTEAD (503)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	56.8	51.1	43.5	.60	19	22.3
	200	46.4	39.0	34.1	.64	29	16.6
Spring	300	49.1	41.2	35.8	.65	30	17.2
	200	44.6	35.7	31.6	.68	35	13.9
Summer	300	38.0	28.9	26.3	.71	42	9.9
	200	42.9	30.9	27.9	.74	48	9.6
Fall	300	49.3	41.4	36.0	.65	30	17.2
	200	49.8	37.3	32.8	.72	44	12.7

NANTUCKET (506)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	57.6	50.1	42.7	.62	24	20.7
	200	49.5	39.6	34.6	.68	35	15.1
Spring	300	48.9	40.6	35.3	.66	31	16.8
	200	44.4	34.2	30.4	.70	41	12.5
Summer	300	39.8	29.5	26.8	.73	45	9.6
	200	43.4	31.2	28.1	.75	50	9.8
Fall	300	47.9	38.8	34.0	.67	34	15.2
	200	48.7	35.6	31.5	.73	47	11.6

LONG BEACH (297)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	47.3	35.9	31.7	.71	42	12.7
	200	46.9	32.4	29.0	.76	53	9.5
Spring	300	42.7	33.7	30.0	.68	37	12.9
	200	41.7	30.0	27.2	.74	48	9.2
Summer	300	26.0	16.9	17.0	.79	57	0
	200	30.1	18.4	18.2	.81	62	0.8
Fall	300	36.5	28.8	26.2	.69	38	10.7
	200	36.7	26.1	24.1	.75	50	7.5

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
ALBUQUERQUE (365)							
Winter	300	44.8	36.3	32.0	.67	34	14.6
	200	42.7	31.6	28.4	.73	45	10.6
Spring	300	40.7	33.8	30.0	.65	30	14.3
	200	39.0	29.2	26.5	.72	44	9.8
Summer	300	24.2	15.7	16.1	.79	57	0.0
	200	29.5	18.6	18.3	.80	61	1.1
Fall	300	36.5	27.7	25.4	.72	44	9.3
	200	40.7	28.5	26.0	.76	51	8.3
FORT WORTH (259)							
Winter	300	45.0	36.9	32.5	.66	33	15.1
	200	43.6	31.8	28.5	.73	47	10.3
Spring	300	41.3	31.0	27.9	.72	44	10.6
	200	43.3	31.6	28.4	.73	47	10.3
Summer	300	23.3	15.8	16.2	.77	54	0.0
	200	29.3	19.0	18.6	.79	57	1.5
Fall	300	37.4	27.3	25.1	.73	47	8.4
	200	40.0	27.2	25.0	.77	54	7.2
LITTLE ROCK (340)							
Winter	300	45.6	36.0	31.8	.69	38	13.7
	200	44.4	33.3	29.7	.72	44	11.5
Spring	300	41.1	31.6	28.4	.70	41	11.4
	200	43.6	29.6	26.8	.77	54	8.2
Summer	300	25.8	17.8	17.7	.76	53	0.4
	200	30.4	21.0	19.5	.76	56	2.6
Fall	300	38.6	27.0	24.8	.76	51	7.5
	200	40.0	28.0	25.6	.76	51	8.0

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

NASHVILLE (327)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	44.4	36.0	31.8	.67	34	14.4
	200	42.7	33.3	29.7	.70	40	12.4
Spring	300	43.3	32.0	28.7	.73	45	10.7
	200	44.6	30.3	27.4	.77	54	8.4
Summer	300	26.6	20.0	19.4	.72	44	3.3
	200	32.4	22.7	21.5	.76	51	5.1
Fall	300	39.2	31.8	28.5	.67	34	12.9
	200	40.2	31.4	28.2	.70	40	11.8

GREENSBORO (317)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	45.4	40.4	35.2	.61	23	19.1
	200	41.7	34.6	30.7	.66	31	14.6
Spring	300	42.5	32.7	29.2	.71	41	12.0
	200	43.6	31.4	28.2	.74	48	10.0
Summer	300	28.5	21.7	20.7	.71	42	5.2
	200	33.8	23.0	21.7	.77	54	5.1
Fall	300	40.4	31.9	28.6	.69	38	12.2
	200	40.5	27.9	25.5	.76	53	7.8

NORFOLK (308)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	50.4	43.8	37.8	.63	25	19.3
	200	45.6	36.9	32.5	.67	34	14.7
Spring	300	45.0					
	200	44.6					
Summer	300	32.4					
	200	38.6					
Fall	300	44.0					
	200	45.0					

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

CHARLESTON, S. C. (208)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	40.4	33.9	30.2	.64	29	14.5
	200	39.0	32.8	29.3	.65	30	14.3
Spring	300	41.3	29.7	27.0	.74	48	9.0
	200	44.2	30.9	28.0	.76	51	8.7
Summer	300	26.6	19.4	19.0	.73	47	2.2
	200	33.2	22.9	21.7	.76	53	4.9
Fall	300	40.0	28.8	26.2	.75	50	8.9
	200	42.1	26.9	24.8	.80	59	6.1

TUCSON (274)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	46.9	29.5	26.8	.80	61	6.9
	200	46.9	26.7	24.6	.84	67	4.9
Spring	300	41.9	33.9	30.2	.67	34	13.4
	200	41.3	29.7	26.9	.74	48	9.3
Summer	300	23.7	19.2	18.8	.67	34	2.7
	200	28.7	20.7	20.0	.74	48	3.5
Fall	300	35.3	26.5	24.4	.72	44	8.6
	200	38.6	29.0	26.4	.77	54	9.7

BIG SPRING (265)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	42.9	31.3	28.2	.73	47	10.0
	200	41.3	31.0	27.9	.77	54	10.7
Spring	300	37.4	27.3	25.1	.73	47	8.2
	200	39.2	27.8	25.5	.75	50	8.0
Summer	300	23.3	18.4	18.2	.68	37	1.3
	200	29.7	22.3	21.2	.72	44	5.4
Fall	300	34.5	24.1	22.6	.76	51	5.9
	200	38.4	25.3	23.5	.78	56	6.0

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

LAKE CHARLES (240)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	39.6	27.7	25.4	.76	51	7.8
	200	40.4	30.3	27.4	.77	54	10.3
Spring	300	37.6	27.8	25.5	.73	45	8.7
	200	40.9	26.6	24.5	.79	57	6.4
Summer	300	23.5	19.0	18.7	.67	34	2.0
	200	30.8	22.8	21.6	.73	45	5.6
Fall	300	36.5	23.7	22.3	.79	57	4.8
	200	39.4	25.6	23.8	.79	57	5.7

BURRWOOD (232)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	37.4	27.7	25.4	.73	45	8.7
	200	39.6	26.1	24.1	.78	56	6.4
Spring	300	35.3	24.0	22.5	.77	54	5.6
	200	39.2	25.5	23.7	.79	57	5.8
Summer	300	22.5	16.6	16.8	.73	45	0
	200	28.9	22.0	21.0	.71	42	5.1
Fall	300	34.9	22.9	21.5	.79	57	4.4
	200	38.8	29.4	22.8	.80	61	5.0

MONTGOMERY (226)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
Winter	300	44.4	29.3	26.6	.78	56	7.7
	200	44.6	27.2	25.0	.81	62	5.8
Spring	300	42.9	33.9	30.2	.68	37	12.9
	200	47.5	30.2	28.9	.77	54	9.2
Summer	300	24.6	19.9	19.3	.67	34	3.9
	200	32.4	25.6	23.8	.69	38	8.5
Fall	300	41.7	28.4	25.9	.77	54	7.8
	200	44.2	28.7	26.2	.79	57	7.0

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
JACKSONVILLE (206)							
Winter	300	40.0	28.0	25.6	.76	51	8.0
	200	41.9	27.2	25.0	.79	57	6.5
Spring	300	38.8	24.4	22.8	.80	61	5.0
	200	45.2	27.6	25.3	.81	62	6.0
Summer	300	22.1	15.0	15.6	.77	54	0
	200	29.3	17.6	17.6	.82	64	0
Fall	300	37.2	22.7	21.5	.81	62	3.8
	200	41.1	25.1	23.4	.81	62	4.9
BROWNSVILLE (250)							
Winter	300	34.3	24.7	23.0	.74	48	6.9
	200	38.6	26.2	24.2	.77	54	6.9
Spring	300	29.5	21.8	20.8	.73	45	4.9
	200	33.6	24.2	22.7	.74	48	6.2
Summer	300	20.0	14.0	14.8	.76	51	0
	200	27.9	19.3	18.9	.76	53	2.0
Fall	300	31.0	20.2	19.6	.79	57	2.5
	200	35.5	21.7	20.7	.81	62	3.4
MIAMI (202)							
Winter	300	37.2	25.7	23.8	.76	.53	6.8
	200	37.0	26.6	24.5	.74	.48	7.8
Spring	300	33.0	21.4	20.5	.79	57	5.5
	200	38.2	25.2	23.4	.78	56	6.0
Summer	300	19.2	14.0	14.8	.73	47	0
	200	28.7	18.9	18.6	.78	56	1.4
Fall	300	32.2	19.6	19.1	.81	62	1.9
	200	39.4	23.2	21.9	.83	65	3.8

Table 8. Seasonal Wind Statistics and Derived Twelve-Hour Forecast Errors (continued)

Season	Level (mb)	σ knots	RP knots	RF knots	r	RVP %	FA %
SAN JUAN, P. R. (525)							
Winter	300	27.7	18.8	18.5	.77	54	1.5
	200	29.9	19.7	19.2	.78	56	2.2
Spring	300	23.9	15.5	15.9	.79	57	0
	200	29.1	19.2	18.8	.78	56	1.8
Summer	300	16.7	13.2	14.2	.69	38	0
	200	23.5	16.2	16.5	.76	53	0
Fall	300	22.1	15.9	16.2	.77	54	0
	200	30.1	19.0	18.6	.80	61	1.7
ALBROOK, C. Z. (806)							
Winter	300	21.5	14.0	14.8	.79	57	0
	200	26.6	18.4	18.2	.76	53	1.0
Spring	300	18.0	11.5	12.8	.80	59	0
	200	23.1	14.8	15.4	.80	59	0
Summer	300	11.2	10.8	12.3	.54	08	0
	200	18.2	16.6	16.8	.58	17	0
Fall	300	13.4	10.6	[illegible]	.68	37	0
	200	19.8	14.1	14.9	.75	50	0

4.4 Analysis of Forecast Error Statistics

Selected quantities from Tables 7 and 8 were plotted on maps and analyzed in order to obtain a clearer picture of the geographical variations. The following charts for 6 hours at 300 mb are presented here to illustrate patterns which were found to be typical:

RP	winter, Figure 1
RP	summer, Figure 2
RVP	winter, Figure 3
RVP	summer, Figure 4
FA	winter, Figure 5
FA	summer, Figure 6

4.4.1. DISTRIBUTION OF PERSISTENCE ERRORS

As noted in paragraph 3.1.4, the maximum persistence errors occur over the northeastern and northwestern U. S.; minimum errors over north central and southern sections. Between winter (Fig. 1) and summer (Fig. 2) the average error decreases by about 1/3 and the entire distribution shifts northward so that the maximum centers are located over southern Canada while a minimum center appears over the southwestern U. S. There seems to be some relationship between the vector mean wind field and the persistence distribution, especially in winter when the axes of maximum wind and maximum RP virtually coincide.

4.4.2. THE REDUCTION IN VARIANCE FIELD

The distribution of RVP in winter (Fig. 3) consists of minima in the eastern, central and northwestern U. S. with increasing values to the south. The principal feature of the summer distribution (Fig. 4) is a large area of maximum reduction over the central U. S., flanked by elongated areas of minimum values to the west and east. From Equations (10) and (22) we find that RVP = 100 [2r - 1], hence the contours in Figures 3 and 4 can be relabelled in terms of the persistence correlation.

4.4.3. FORECAST ADVANTAGE DISTRIBUTION

It is apparent that 6-hour subjective forecasts offer very little advantage over persistence. The maximum forecast gain is achieved in the winter (Fig. 5) when an advantage of 10% over persistence is attained in the northeastern and northwestern U. S. While small, this forecast advantage is

not fortuitous; a rough estimate of the probable effect of observational uncertainties in these regions shows them to be an order of magnitude smaller than the forecast advantage.

The results in summer (Fig 6) indicate a decisive advantage for persistence. In fact south of 40°N the value of FA is negative everywhere. The only areas of positive forecast advantage are north of 40°N, reaching a maximum of about 5% in southern Canada. At 200 mb the gain of subjective forecasts is even less than at 300 mb except in the summer where the 200-mb values are larger for a few stations.

The performance of 12-hour subjective forecasts (Table 8) show a considerable improvement over the 6-hour results. For example at 300 mb in winter the 12-hour forecast advantage is greater than 20% over the northeastern and northwestern U. S. Also, in the summer the contour of zero advantage at 300 mb lies along the southern border of the U. S.

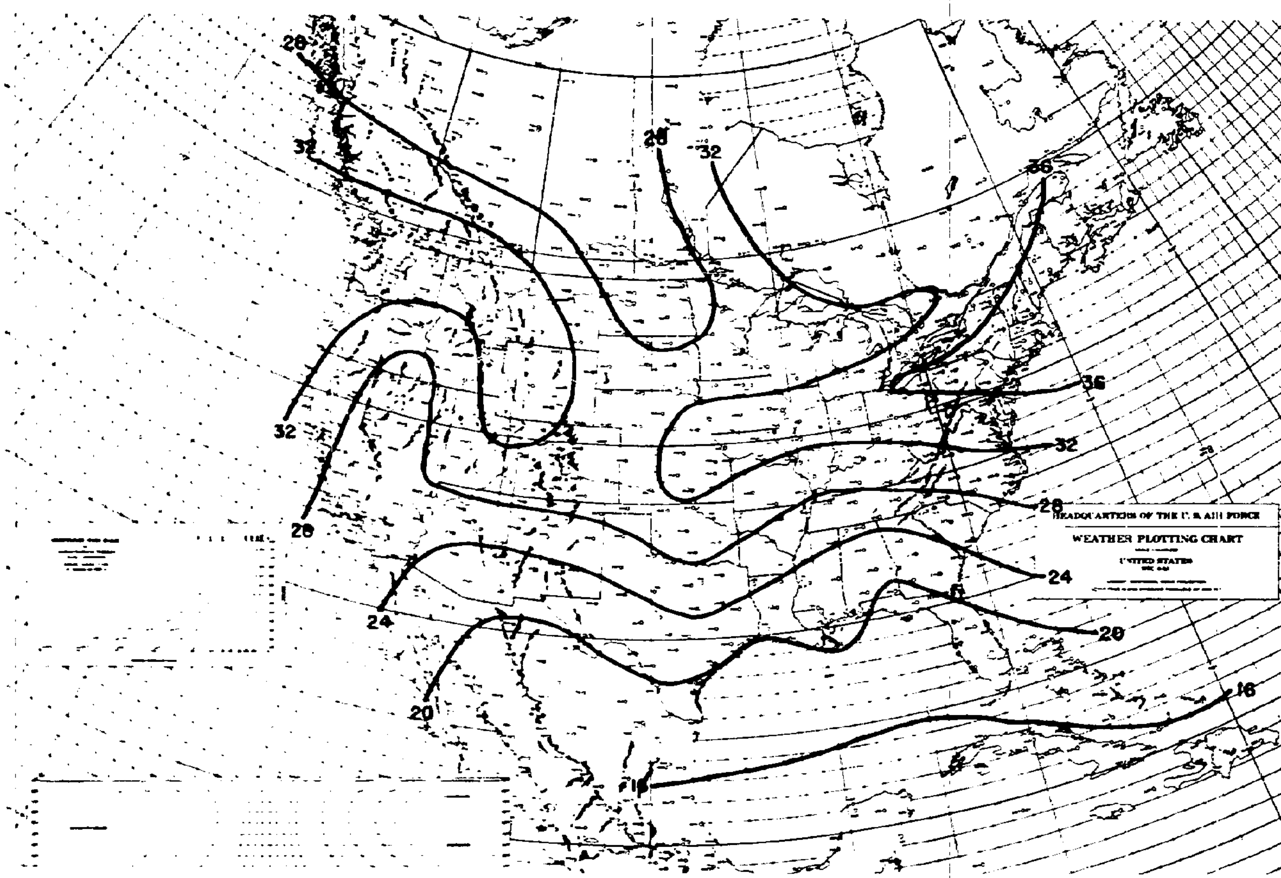

Figure 1. RP, Root Mean Square Error of Six-Hour Persistence Forecasts (knots), Winter, 300mb.

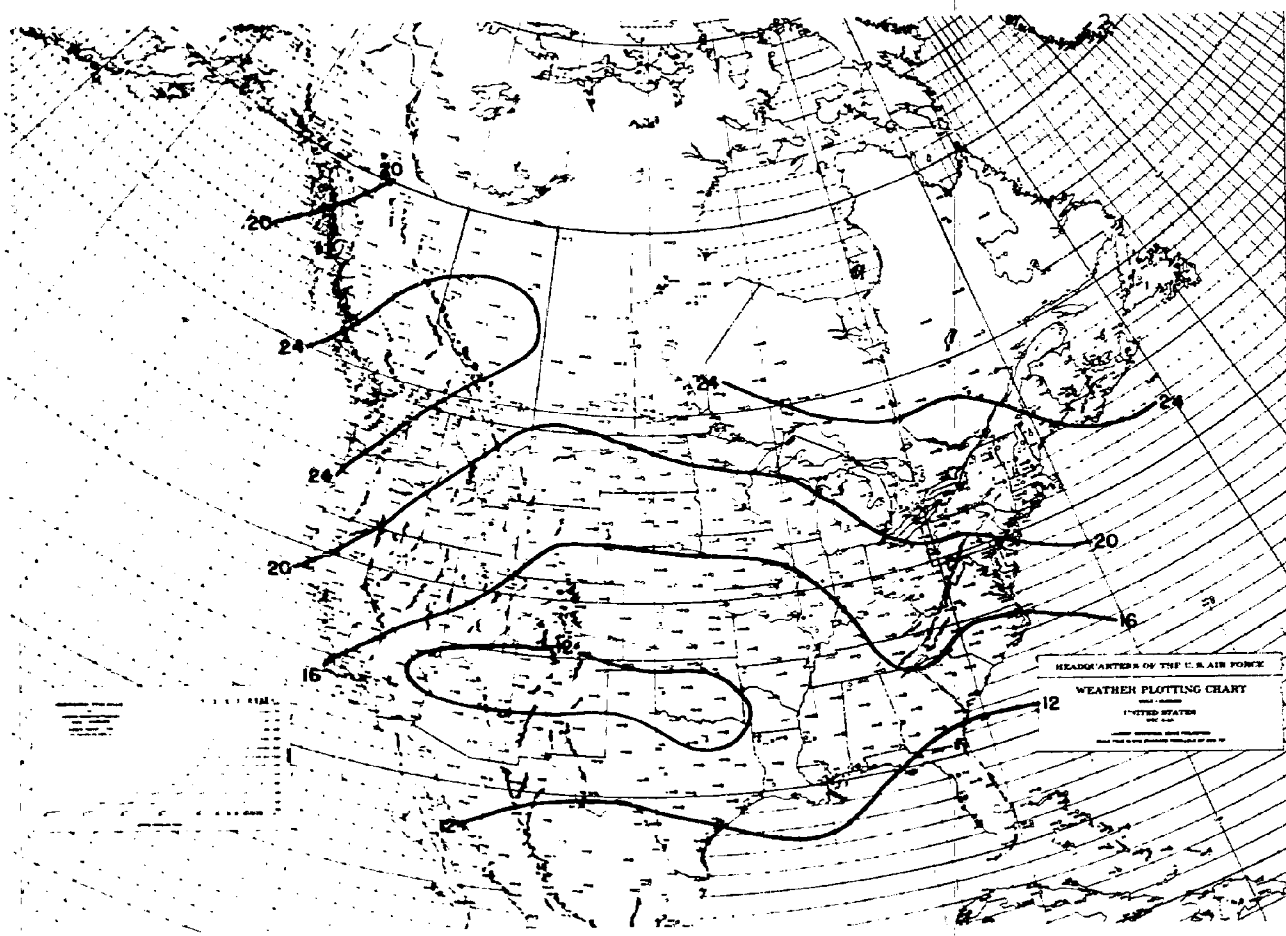

Figure 2. RP, Root Mean Square Error of Six-Hour Persistence Forecasts (knots), Summer, 300mb.

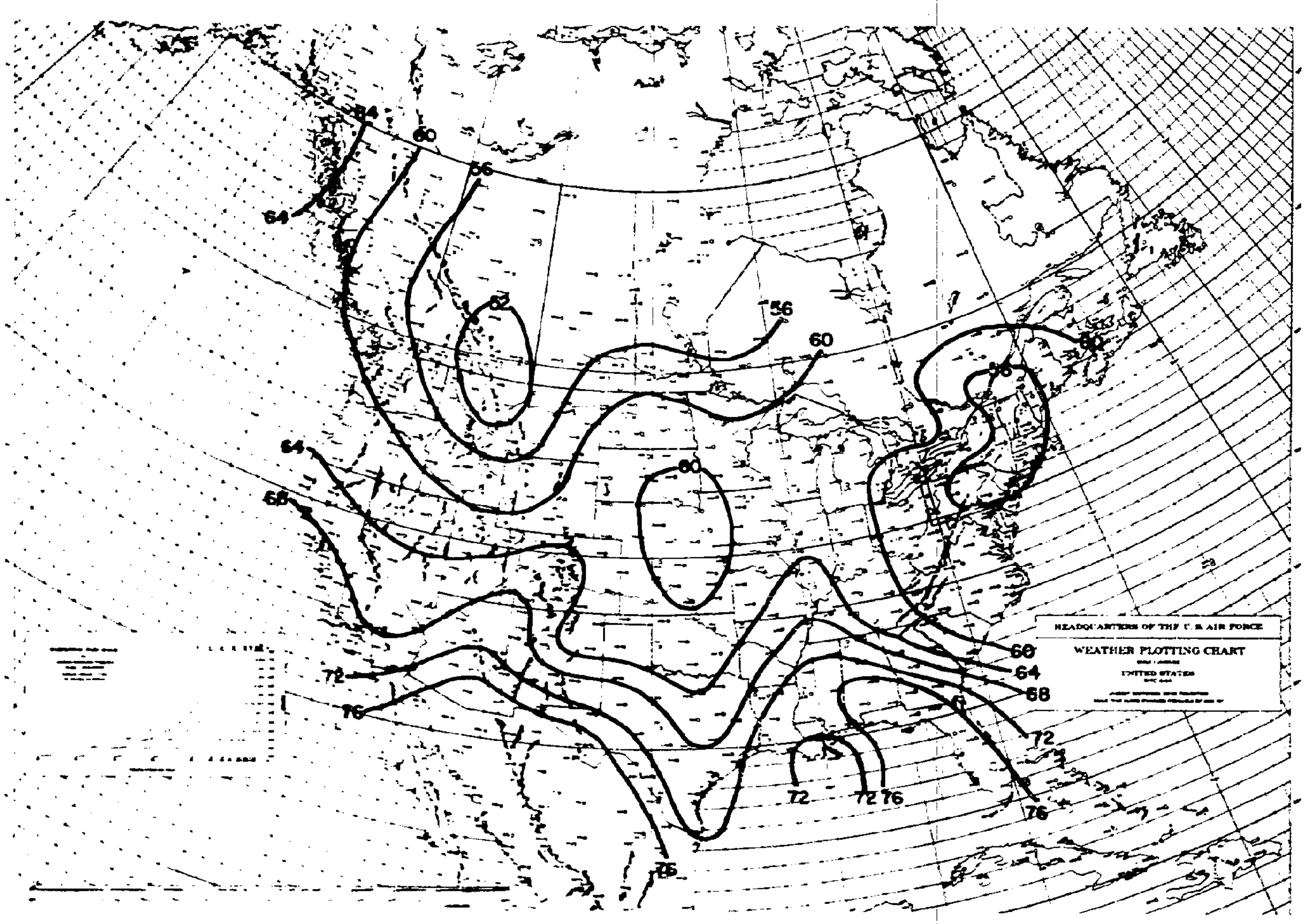

Figure 3. EVP, Percent (%) Reduction in Variance of Six-Hour Persistence Forecasts, Winter, 300mb.

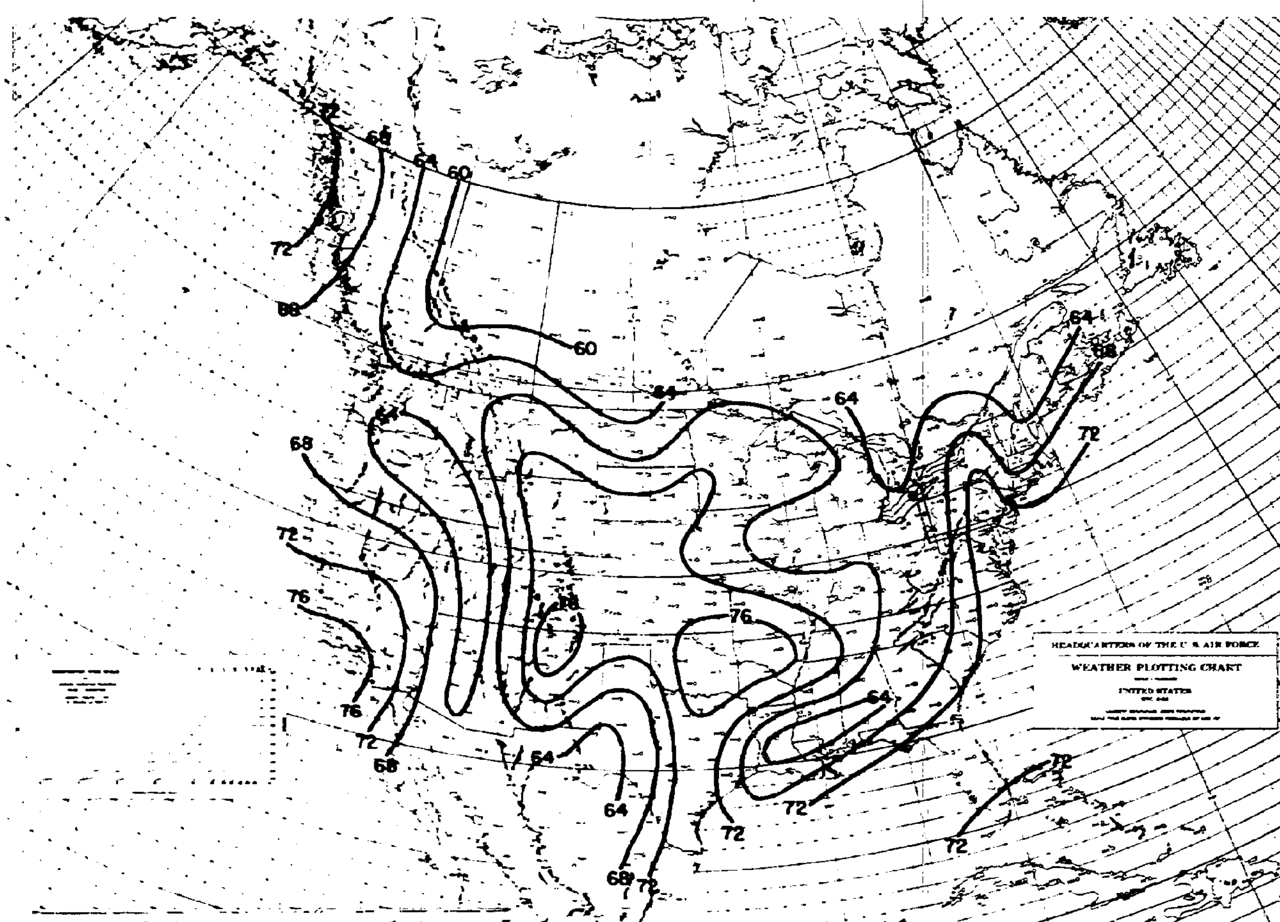

Figure 4. RVP, Percent (%) Reduction in Variance of Six-Hour Persistence Forecasts, Summer, 300mb.

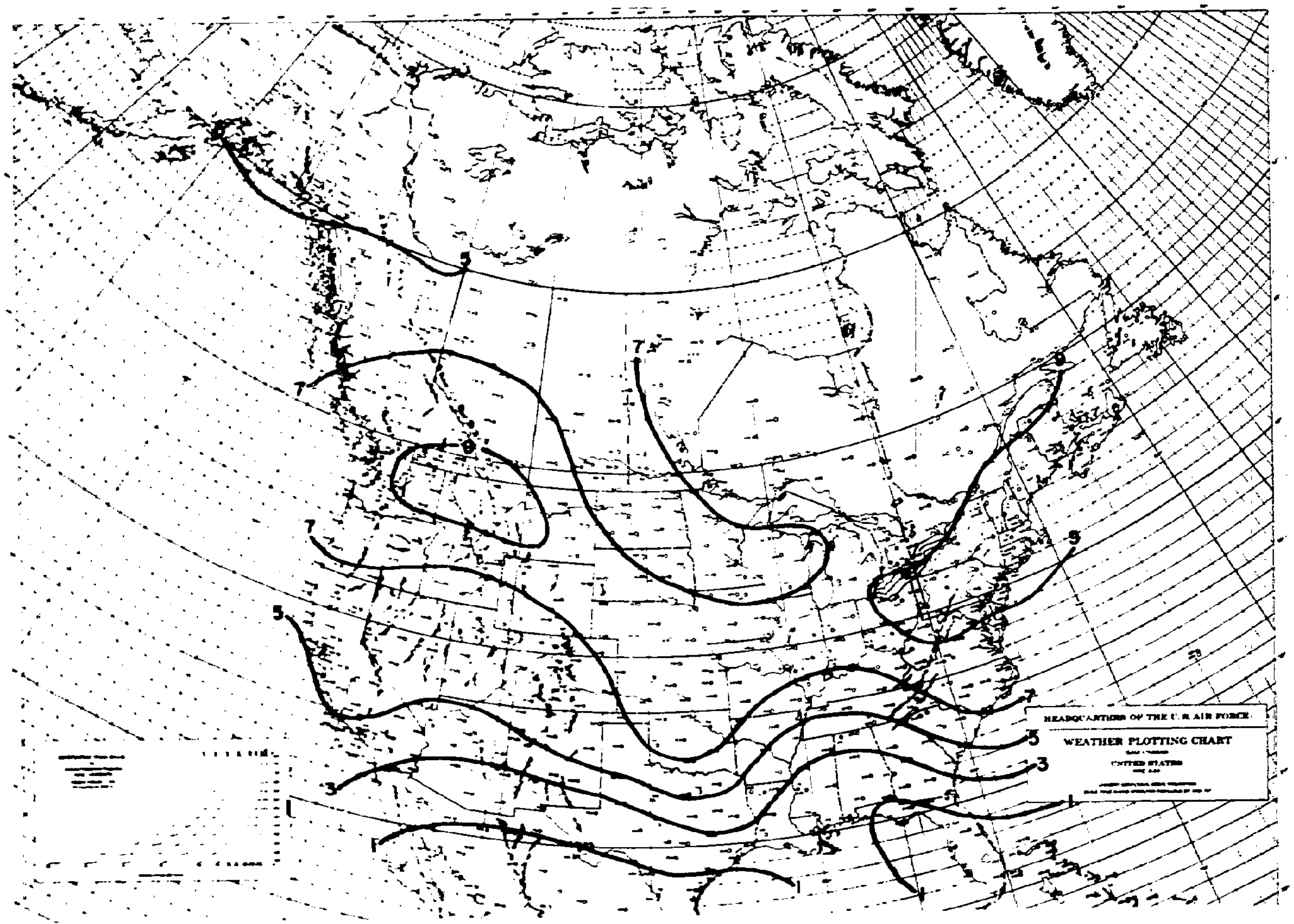

Figure 5. FA, Forecasts Advantage (%) for Six-Hour Subjective Forecasts, Winter, 300mb.

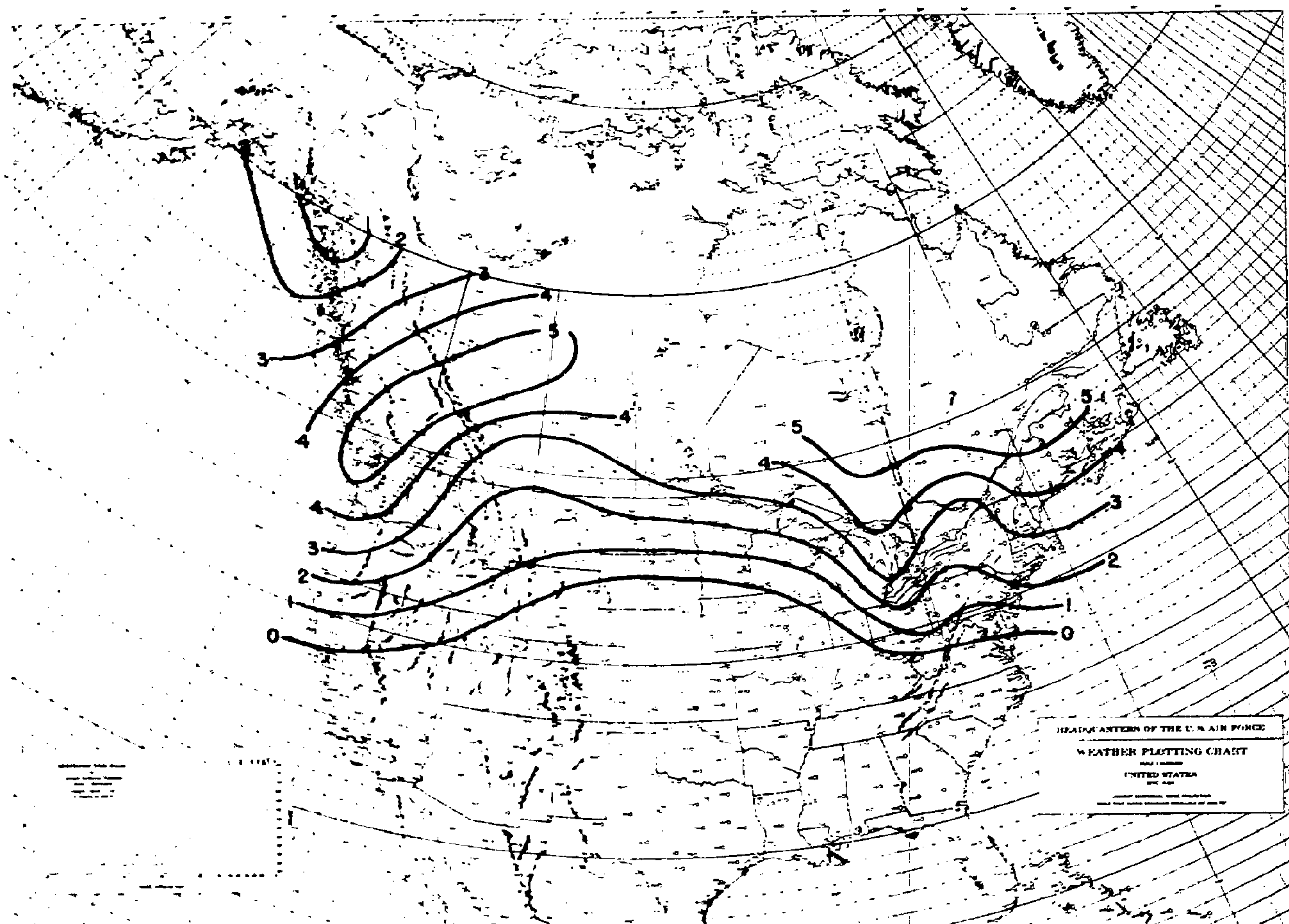

Figure [illegible]. FA, Forecast Advantage ([illegible]) for Six-Hour Subjective Forecasts, Summer, 300mb.

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AF Cambridge Research Laboratories, Bedford, Mass. Geophysics Research Directorate
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AFCRL-62-682 Unclassified report

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1. Meteorology—wind

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